MINERALS ENGINEERING CENTRE

TECHNICAL UNIVERSITY OF NOVA SCOTIA

FINAL REPORT

ON

INVESTIGATION OF TREATMENT OF PINE BROOK BARITE
TO OBTAIN MUD-GRADE BARITE CONCENTRATE

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SUMMARY

This report contains details of test work carried out on Pine Brook barite ore from Cape Breton, Nova Scotia. The work consisted of four phases: sample collection, bench scale tests, pilot plant tests and design of a conceptual flow diagram of a treatment plant.

A blended head sample was prepared by crushing and mixing equal weights of the low and high grade barite ore, resulting in a feed grade of about 50% barite. The specific gravities of individual particles were determined to assess barite distributions and to observe the appearance of particles of various grades. Dense liquid separation tests were carried out on five size fractions in the range of 3.5 to 200 mesh of the head sample at four specific gravities. The dense liquid separation results indicated that mud grade barite concentrate may be produced from the head sample at acceptable barite recoveries as long as the separator is able to achieve a sharp separation.

Laboratory bench tests and pilot plant work included Tri-Flo separator tests, jigging tests, Humphreys and Reichert spiral tests and shaking tabling. The Tri-Flo separation tests were subcontracted to Lakefield Research, Ontario. Tri-Flo separation tests showed that, on the 3.5 to 30 mesh feed, mud-grade barite (S.G.4.2) could be produced at 75% barite recovery.

Altogether thirty five jigging tests were run on the 3.5 mesh to zero head sample on a 4 in. by 6 in. Denver mineral jig. Good concentration results were obtained when high grade barite ragging was used. The most important operating variables were the depth of ragging bed and the water flow rate. Specific feed rates up to 14 t/hm^2 were found to be best, giving barite recoveries up to 60% at mud grade specification.

Neither the Humphreys nor the Reichert spiral concentrators achieved sufficiently high concentrate grade for use as mud grade barite.

Thus, it appears that spiral concentration is not a suitable method for use with Pine Brook barite ore.

Ten shaking tabling tests were run. The ore was ground to finer than 1 mm, and to finer than 0.5 mm. Good concentration results were obtained on the finer sample, recovering up to 53% barite at mud grade. Shaking tabling also worked well on the jig tailing ground to finer than 0.5 mm, recovering up to 40% barite values from the tailing and increasing the combined barite recovery to about 73%.

A conceptual design of a plant to treat 200 tonnes daily of Pine Brook barite ore to produce mud grade barite was drawn up on the basis of the test results. A relatively simple process of two stage crushing followed by jigging and retreatment of the jig tailing was chosen. The jig concentrate is of sufficiently high grade to form the final concentrate. The jig tailing is dewatered, ground in a rod mill, and treated on shaking tables. The shaking table tailing is rejected as final tailing, and the shaking table concentrate, with the jig concentrate, dewatered, filtered, dried and ground in a ring-roller mill. The barite product satisfies the requirements for mud grade barite as its specific gravity is over 4.2, its soluble alkaline earth metal content, as calcium, well below 250 ppm, and its size finer than 325 mesh. The estimated barite recovery of the plant is 73% and the concentrate amounts to approximately 40% of the feed, that is a concentration ratio of 2.5. The flow diagram, and the calculations on which the flow circuit and equipment sizing were based, are included.

Sommaire

Ce rapport détaille les travaux d'essai executés sur le minerai de baryte de Pine Brook à l'île du Cap-Bréton (Nouvelle-Ecosse). Le travail consista en quatre phases: le prélèvement d'échantillons, des essais à l'échelle d'un banc, des essais d'installation pilote et le dessin d'un diagramme d'écoulement conceptuel d'une usine de traitement.

Un échantillon mélangé d'alimentation fut préparé en concassant et mélangeant le même poids de minerai de baryte à basse teneur et à haute teneur, ce qui résulte en une teneur d'alimentation d'à peu près 50% de baryte. Le poids spécifique des particules individuelles fut déterminé afin d'évaluer la distribution du baryte et d'observer l'apparence des grains de différentes teneurs. Des essais de séparation des liquides denses furent exécutés sur cinq fractions granulométriques de 3,5 et 200 mailles de l'échantillon d'alimentation à quatre poids spécifique. Les résultats de séparation des liquides denses indiquent que le concentré de boue de forage pourrait être produit à partir de l'échantillon d'alimentation à un rendement acceptable de baryte, pourvu que le trieur soit capable de produire une séparation nette.

Des essais au banc en laboratoire et des travaux d'installation pilote comprenèrent des essais de séparation Tri-Flo, des essais de concentration au bac, des essais de spirale Humphreys et Reichert, et des essais sur la table à secousses. Les essais de séparation Tri-Flo furent sous-traités à Lakefield Research en Ontario. Les essais de séparation démontrent que, à une alimentation granulométrique de 3,5 à 30, le boue de forage (S.G. 4,2) pourrait se produire à un rendement de 75% de baryte.

En tout, 35 essais de concentration au bac furent exécutés sur une maille de 3,5 à un échantillon d'alimentation de zéro, sur un jig de minerai Denver mesurant 4 po par 6 po. Une bonne concentration fut obtenue lorsque le lit de baryte à haute teneur fut employé. Les variables d'opération les plus importantes furent la profondeur du lit et la vitesse de l'écoulement d'eau. Il fut observé que des taux d'alimentation spécifiques jusqu'à 14 t/hm^2 sont les plus avantageux, produisant des rendements de baryte de 60% à une spécification de boue de forage.

Ni le concentrateur en spirale Humphreys ou celui de Reichert ont atteint une teneur de concentré suffisamment haute pour employer en tant que boue de forage. Donc, il semble que la concentration en spirale n'est pas une méthode appropriée à utiliser avec le minerai de baryte de Pine Brook.

Dix tables à secousses furent opérées. Le minerai fut meulé plus fin qu'un millimètre, et que 0,5 millimètre. Une bonne concentration fut obtenue sur l'échantillon plus fin, avec un rendement jusqu'à 53% de boue de forage. La table à secousses est également effective sur le "jig tailing", à un broyage plus fine que 0,5 mm et un rendement jusqu'à 40% de valeur en baryte des tailings et une augmentation du rendement de baryte combiné d'à peu près 73%.

Un plan conceptuel d'une usine pour traiter 200 tonnes par jour (pour que le minerai de baryte de Pine Brook produise le boue de forage) fut dessiné selon les résultats des essais. Une procédure assez simple de concassage à deux étapes, suivi par la concentration au bac et retraitement du "jig tailings" fut choisie. Le concentré de jig est d'une teneur suffisamment haute pour former le concentré final. Le jig tailings est asséché, broyé dans un broyeur à barres et traité sur une table à secousses. Le tailings de la table à secousses est rejeté comme tailings final et le concentré de la table à secousses (avec le concentré en jig) est épaissit, filtré, asséché et meulé dans un broyeur "ring-roller". Le produit de baryte satisfait les exigeances pour une teneur de baryte en boue de forage, car le poids spécifique excède 4,2, la teneur en métal alcalino-terreux soluble, comme le calcium, est bien moins que 250 ppm et la grosseur plus fine qu'une maille de 325. Le rendement de baryte estimé de l'usine est de 73% et le concentré s'approche à 40% de l'alimentation, c'est-à-dire un taux de concentration de 2,5. Le diagramme d'écoulement et les calculations sur lesquelles le circuit d'écoulement et la mesurage de l'équipement sont basés, sont inclus.

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1. INTRODUCTION

The investigation was divided into four phases as follows:

Phase I: Obtaining the 6 - 10 tonne bulk sample of Pine Brook barite. This was carried out by the Nova Scotia Department of Mines and Energy. The bulk sample consisted of four drums of high grade and eleven drums of low grade ore.

Phase II: Bench-scale tests using gravity concentration methods to investigate fineness of grind necessary to obtain the required mud-grade barite at acceptable recoveries.

A head sample was prepared from the ore received from the Nova Scotia Department of Mines and Energy by crushing equal weights of high and low grade samples to finer than 3 1/2 mesh using a spring roll crusher, and thoroughly mixing the products. The blended head sample was subjected to chemical and size analyses.

To assess the density distributions, densities of individual particles were determined for both the high and low grade barite ore samples. Five size fractions of the blended head sample, namely 3 1/2 to 6 mesh, 6 to 18 mesh, 18 to 35 mesh, 35 to 70 mesh and 70 to 200 mesh were float-and-sink analyzed at 2.95, 3.23, 3.49 and 4.27 specific gravities. From the dense liquid analysis, results of ideal separation were predicted.

Phase III: Pilot plant tests conducted for the recovery of mud-grade barite using information obtained from bench-scale work.

The pilot plant work included Tri-Flo separator tests, jigging tests, Humphreys and Reichert spiral tests, and shaking tabling.

The Tri-Flo separation tests were subcontracted to Lakefield Research, Ontario. These tests were carried out on a 3 1/2 to 30 mesh fraction of the blended head sample.

A Denver Mineral Jig of 102 mm x 152 mm (4 in. x 6 in.) screen area was used for the separation of 3 1/2 mesh to 0 blended head sample at several operating conditions.

The Spiral tests were conducted on samples of the blended head ore ground to below 1 mm and 0.5 mm respectively.

Shaking table tests were carried out on a Wilfley Laboratory Concentrating Table, Type 13B, with a deck size of 1270 mm x 610 mm. Finer than 1 mm, and finer than 0.5 mm blended ore was separated at several settings of operating variables.

Phase IV: Evaluation of test work and development of a flow diagram of a plant capable of treating Pine Brook Barite ore at 200 tonnes per day to produce mud-grade barite concentrate.

On the basis of the test results, a conceptual design of a plant capable of treating 200 tonnes of Pine Brook barite ore daily was drawn up. In selecting the type of flow diagram, consideration was given to the technical implications of the test results, together with financial considerations regarding the capital and operating costs of the proposed plant. The design includes details of feed preparation, concentration and solid-liquid separation sections required for the preparation of mud-grade barite from Pine Brook ore.

PHASE II

2. SAMPLE PREPARATION

The Pine Brook barite received consisted of four drums of high grade ore and eleven drums of low grade ore. Since the samples were kept outside prior to delivery to the Minerals Engineering Centre, the drums contained considerable quantities of water in addition to the barite. Before any sample preparation could commence, it was necessary to spread the sample for air drying, turning the barite ore over from time to time. The drying process took a considerable time and delayed commencement of the planned work.

The four drums of high grade ore were crushed in a jaw crusher followed by rolls crusher, thoroughly mixed, and a sample prepared for barite analysis. The eleven drums of low grade ore were crushed similarly, homogenized, and a representative sample was taken from each drum for barite analysis.

The weights and barite contents of these samples are given in Table 1.

A composite sample of the low grade ore was made for screen analysis at 3 1/2 mesh and 100 mesh. The size fractions were weighed and sampled and barite analysis carried out on each sample. The results are given in Table 2.

2000 lbs of high grade ore were mixed with 2000 lbs of low grade material. The sample was then dry screened at 3 1/2 mesh and the oversize stage-crushed to finer than 3 1/2 mesh in a cone crusher by repeated screening and crushing. This formed a head sample for further test work. A representative sample was prepared for chemical analysis, screen analysis and dense liquid analysis.

TABLE 1: Weights and Barite Contents of Samples

Sample designation	Weight (lbs) air dried	$BaSO_4$, % dry basis
High grade from four drums	3484	71.56
Low grade drum A	642	24.20
B	695	27.82
C	665	24.49
D	640	24.75
E	652	19.80
F	710	19.52
G	660	24.31
H	716	22.91
I	622	21.71
J	630	24.51
K	656	18.64
Total weight of low grade ore:	7288 lbs.	23.26
Total weight of ore	10772 lbs.	38.88

TABLE 2: Details of Low Grade Composite Sample.

Mesh	Weight, %	$BaSO_4$,%	Barite Distribution, %
+ 3 1/2	19.3	43.29	35.93
3 1/2 to 100	51.9	22.81	50.91
- 100	28.8	10.63	13.16
Reconstituted head grade		23.26	

Results of chemical analysis of the head sample of blended ore are given in Table 3.

Table 3: Results of Chemical Analysis of Blended Head Sample.

%

$BaSO_4$	$SrSO_4$	SiO_2	Al_2O_3	Fe_2O_3	CaO	CO_2	C
46.41	1.30	26.89	6.03	2.34	7.09	2.75	0.97

ppm

Cu	Pb	Zn	Cd
400	600	1470	18

A sufficient amount of the blended head sample was wet sieved at 0.5 mm to obtain 120 kg of 3 1/2 mesh to 0.5 mm deslimed feed for Tri-Flo tests. This sample was dried and shipped to Lakefield Research of Canada Limited.

2.1 Discussion of Sample Preparation

Although there was some grade variation amongst the low grade ore samples within each drum, there was less than five percent barite grade difference between the highest and the reconstituted head grade and between the lowest and the reconstituted head grade (Table 1). This ore contained a good deal of clayey material, some of which was porous. The coarser fractions of the low grade ore were considerably higher grade than the finer fractions (Table 2). This was probably due to the easy disintegration of clayey material.

The four drums of high grade ore were markedly different from the low grade as the high grade was solid ore with minimal clayey content.

The grade of the blended head sample was about 46.5%. The sample contained 1.3% celestite (Table 3). Main contaminants were silicates as clayey materials. The copper, lead, zinc and cadmium contents were determined to assess pollution problems encountered in tailings disposal.

3. SCREEN ANALYSIS

The blended head sample was size analyzed at 3 1/2, 6, 18, 35, 70 and 200 mesh sizes. From each size fraction an analytical sample was prepared for barite analysis. The results are given in Table 4.

TABLE 4: Details of Blended Head Sample.

Mesh	Weight, %	$BaSO_4$,%	Barite Distribution, %
3 1/2 to 6	13.8	57.23	16.94
6 to 18	37.1	56.59	45.02
18 to 35	11.1	48.62	11.57
35 to 70	9.1	44.54	8.69
70 to 200	7.5	40.96	6.59
-200	21.4	24.38	11.19
Reconstituted head grade		46.63	

3.1 Discussion of Screen Analysis

The blended head sample showed an increase in barite grade with size, but the minus 200 mesh fraction still contained over 24% barite (Table 4), while the low grade contained less than 11% in the minus 100 mesh fraction (Table 2). The weight percentage of the minus 200 mesh fraction of the blended ore sample was also substantial at 21.4%.

4. MICROSCOPIC EXAMINATION

Examination of mineral samples with a stereoscopic microscope showed that the ore consisted of particles covering the whole range of barite grades from very low to almost 100%. There were some clayey particles which appeared to be porous. Generally, the higher grade particles were lighter in colour and seemed to be fragments of larger solid particles.

5. SPECIFIC GRAVITIES OF INDIVIDUAL PARTICLES

The specific gravities of 30 high grade and 30 low grade particles sized between 3/8" to 1/4" were determined by weighing each particle first in air and then when immersed in water. The specific gravity values for the individual particles are given in Tables 5 and 6, while their frequency distributions are shown in Figures 1 and 2.

TABLE 5: Specific Gravities of Particles in High Grade Sample.

Particle Number	1	2	3	4	5	6	7	8	9	10
Specific Gravity	4.38	4.28	3.92	4.03	3.94	4.27	4.07	4.17	4.25	3.70

Particle Number	11	12	13	14	15	16	17	18	19	20
Specific Gravity	3.75	4.31	3.54	4.13	3.91	4.25	4.27	4.27	3.08	4.13

Particle Number	21	22	23	24	25	26	27	28	29	30
Specific Gravity	3.85	4.16	3.54	3.65	4.27	4.40	4.05	4.36	3.28	4.28

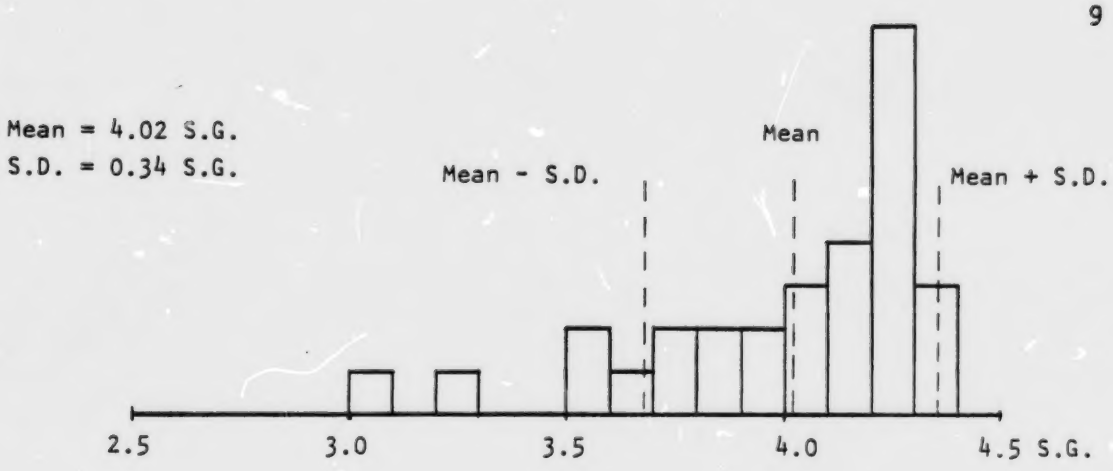


FIGURE 1: Frequency Distribution of Particles in High Grade Sample.

TABLE 6: Specific Gravities of Particles in Low Grade Sample.

Particle Number	1	2	3	4	5	6	7	8	9	10
Specific Gravity	2.44	2.50	3.85	2.79	2.40	2.45	2.55	4.35	2.57	2.47

Particle Number	11	12	13	14	15	16	17	18	19	20
Specific Gravity	4.16	3.51	2.59	2.76	3.89	2.61	2.61	2.37	2.51	2.44

Particle Number	21	22	23	24	25	26	27	28	29	30
Specific Gravity	3.02	2.65	2.57	2.98	2.58	4.23	2.98	2.42	2.78	2.57

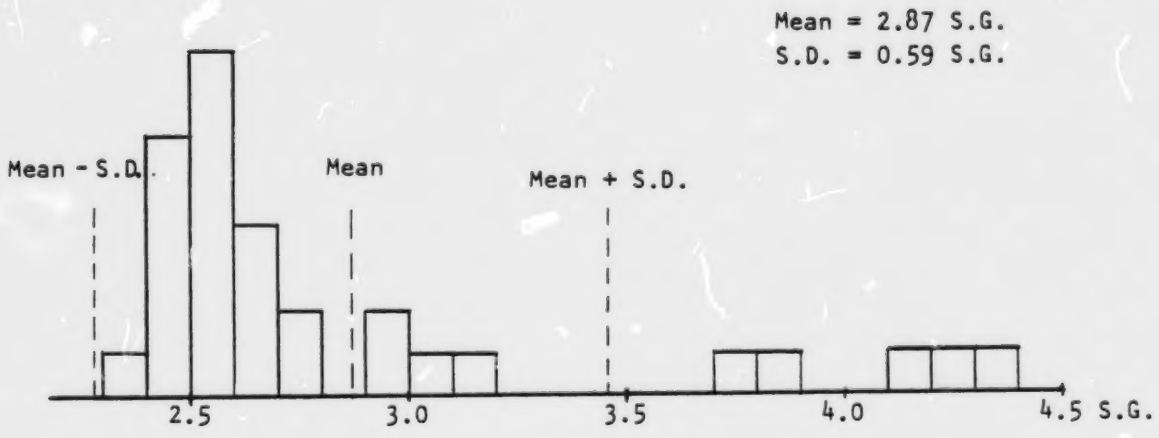


FIGURE 2: Frequency Distribution of Particles in Low Grade Sample.

5.1 Discussion of specific gravities of individual particles

The frequency distribution of individual particles of various specific gravities showed that, in the high grade sample, most particles had specific gravities over 3.5, but even the high grade sample was far from liberated at the noted particle sizes. The low grade sample also contained about 17% above 3.5 and 10% above 4 specific gravity, but most of the material was of low specific gravity and of porous nature.

6. DENSE LIQUID SEPARATION TESTS

Dense liquid separation tests were carried out on five size fractions of the blended head sample. The size ranges of the fractions were: 3 1/2 - 6 mesh, 6 - 18 mesh, 18 - 35 mesh, 35 - 70 mesh, 70 - 200 mesh and minus 200 mesh. The minus 200 mesh fraction was excluded from the tests. The weight percentages and barite distributions, expressed both on feed basis and minus 200 mesh fines removed basis, are given in Table 7. The barite contents of the size fractions are also given.

The size fractions were first separated in tetra-bromoethane at 2.95 S.G. This was done to leave smaller weight fractions to be separated in the very expensive Clerici solutions. Further dense liquid separations at 3.23, 3.49 and 4.27 S.G.s were carried out in Clerici solutions. In order to have sufficient (representative) samples at the various S.G. separations, the higher density separations were always carried out on samples of the sink products of the 2.95 S.G. separation. The results of float and sink analysis relating to these sink products are shown in Table 8.

The specific gravities of float and sink fractions were also determined. These are given in Table 9.

TABLE 7

Weight and Barite Distributions and Assays of the Size Fractions of Blended Head Sample

Size Range, Mesh	Weight, %, Feed Basis	Weight, %, 3 1/2-200 mesh	$BaSO_4$,%	Barite Dist. %, Feed Basis	Barite Dist. % 3 1/2-200 mesh
3 1/2 to 6	13.78	17.53	57.23	16.91	19.04
6 to 18	37.14	47.23	56.59	45.06	50.73
18 to 35	11.09	14.10	48.62	11.56	13.01
35 to 70	9.14	11.62	44.54	8.73	9.82
70 to 200	7.49	9.52	40.96	6.58	7.40
- 200	21.36	-	24.38	11.16	-
Feed	100	-	46.64	100	-
3 1/2 to 200 Mesh	78.65	100	52.69	-	100

TABLE 8

Float and Sink Analyses of the 2.95 S.G. Sink Products of the Size Fractions

Size Range, Mesh		Weight, %				$BaSO_4$, %				Barite Distribution, %			
		2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.	2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.	2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.
3 1/5 to 6,	Sink	74.21	91.20	85.44	17.05	80.13	87.05	88.27	95.08	99.23	98.71	94.04	20.79
	Float	25.79	8.80	14.56	82.95	1.79	11.83	32.85	74.48	0.77	1.29	5.96	79.21
6 to 18,	Sink	67.89	87.81	84.85	23.16	79.73	88.36	88.94	94.62	98.71	97.77	94.85	26.80
	Float	32.11	12.19	15.15	76.84	2.21	14.50	27.07	77.90	1.29	2.23	5.15	73.20
18 to 35,	Sink	64.63	81.75	78.21	29.29	74.70	88.85	88.77	94.84	99.42	94.19	94.02	37.49
	Float	35.37	18.25	21.79	70.71	0.80	24.56	20.26	65.52	0.58	5.81	5.98	62.51
35 to 70,	Sink	58.57	82.23	76.95	32.47	72.61	88.63	90.82	95.02	99.33	95.09	93.72	41.92
	Float	41.43	17.77	23.05	67.53	0.69	21.16	20.28	63.29	0.67	4.91	6.28	58.08
70 to 200,	Sink	51.38	84.85	78.48	36.29	74.69	89.41	91.52	94.32	99.07	97.27	93.41	45.12
	Float	48.62	15.15	21.52	63.71	0.74	14.04	21.66	65.36	0.93	2.73	6.09	54.88

TABLE 9

Specific Gravities of Float and Sink Analysis Fractions and Reconstituted Grades of Size Fractions

Size Range, Mesh		Specific Gravity			Reconstituted Grade of Size Fraction $BaSO_4$ %
		3.23 S.G. Fraction	3.49 S.G. Fraction	4.27 S.G. Fraction	
3 1/2 to 6	Sink	4.11	4.22	4.20	59.93
	Float	3.09	3.35	3.87	
6 to 18,	Sink	4.16	4.28	4.37	54.83
	Float	3.15	3.22	3.92	
18 to 35,	Sink	4.18	4.32	4.46	48.55
	Float	3.03	3.12	3.71	
35 to 70,	Sink	4.20	4.32	4.48	42.81
	Float	3.02	3.11	3.71	
70 to 2000,	Sink	4.27	4.41	4.49	38.74
	Float	2.81	3.17	3.76	

Head 51.91

The weight percentages and barite distributions have been recalculated to relate to the size fractions as if the size fractions were float and sink analyzed sequentially from a single sample. These results are shown in Table 10.

The float and sink analysis results expressed on float and sink head sample basis are given in Table 11. Here the weights of size fractions, separated into five float and sink products, total one hundred percentage weight and the distributions of these fractions also total one hundred percent for the float and sink head sample.

The distributions of barite values given in Table 12 were used in the calculation of weight percentages and barite distributions for the float and sink head sample in Table 11. Table 12 also contains the

TABLE 10

Float and Sink Analysis of Size Fractions

Size Range, Mesh		Weight, % (Size Fraction) 2.95 S.G.	3.23 S.G.	3.49 S.G.	4.75 S.G.	Barite Dist., % (Size Fraction) 2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.
3 1/2 to 6,	Sink	74.21	67.68	63.41	12.65	99.23	98.31	93.40	20.07
	Float	25.79	6.53	4.27	50.76	0.77	0.92	4.91	73.33
6 to 18,	Sink	67.89	59.61	57.60	15.72	98.71	96.05	93.42	27.12
	Float	32.11	8.28	2.01	41.88	1.29	2.66	2.63	66.30
18 to 35,	Sink	64.63	52.84	50.55	18.93	99.42	96.68	92.40	36.97
	Float	35.37	11.79	2.29	31.62	0.58	2.74	4.27	55.43
35 to 70,	Sink	58.57	48.16	45.07	19.02	99.33	99.70	95.61	42.21
	Float	41.43	10.41	3.09	26.05	0.67	-0.37	4.09	53.39
70 to 200,	Sink	51.38	43.60	40.32	18.65	99.07	100.63	95.26	45.41
	Float	48.62	7.78	3.28	21.67	0.93	-1.57	5.37	49.85

TABLE 11

Weight Percentages and Distributions Expressed On Float and Sink Head Basis

Size Range, Mesh		Weight, %, Float/Sink Head Basis				Barite Distribution, % Float/Sink Head Basis			
		2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.	2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.
3 1/2 to 6,	Sink	13.01	11.86	11.12	2.22	20.08	19.89	18.91	4.07
	Float	4.52	1.14	0.75	8.90	0.16	0.19	0.98	14.84
6 to 18,	Sink	32.06	28.15	27.20	7.42	49.24	47.91	46.60	13.52
	Float	15.17	3.91	0.95	19.78	0.65	1.33	1.31	33.08
18 to 35,	Sink	9.11	7.45	7.13	2.67	13.11	12.75	12.19	4.88
	Float	4.99	1.66	0.32	4.46	0.08	0.36	0.56	7.31
35 to 70,	Sink	6.81	5.60	5.24	2.21	9.53	9.56	9.17	4.05
	Float	4.81	1.21	0.36	3.03	0.06	-0.04	0.40	5.12
70 to 200	Sink	4.89	4.15	3.84	1.78	7.04	7.15	6.77	3.23
	Float	4.63	0.74	0.31	2.06	0.07	-0.11	0.38	3.54
3 1/2 to 200	Sink	65.88	57.21	54.53	16.30	99.00	97.26	93.64	29.75
	Float	34.12	8.66	2.69	38.23	1.02	2.73	3.63	63.89
TOTAL		100.00	65.87	57.22	54.53	100.02	98.99	97.27	93.64

TABLE 12

Distribution of Barite Values and Tabulation of Cumulative Results

Size Range, Mesh		Barite Values * Size Fraction Basis				Barite Values Float/Sink Head Basis			
		2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.	2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.
3 1/2 to 6,	Sink	5946.45	5891.54	5597.20	1202.76	1042.49	1032.41	981.56	211.08
	Float	46.16	54.91	294.34	4394.44	8.09	10.08	50.85	770.48
6 to 18,	Sink	5412.87	5267.14	5122.94	1487.43	2556.14	2487.33	2419.17	702.08
	Float	70.96	145.73	144.20	3635.51	33.53	68.81	68.16	1717.09
18 to 35,	Sink	4827.86	4694.83	4487.32	1795.32	680.52	661.93	632.03	253.22
	Float	28.30	133.03	207.51	2692.00	3.99	18.59	29.00	379.71
35 to 70,	Sink	4252.77	4268.42	4093.26	1807.28	494.47	496.33	475.90	202.99
	Float	28.59	-15.65	175.16	2285.98	3.32	-1.86	20.43	265.91
70 to 200	Sink	3837.57	3898.28	3690.09	1759.07	365.23	372.05	351.44	167.89
	Float	35.98	-60.71	208.19	1931.02	4.64	-5.82	19.61	183.55
Cumulative	Barite Values in Concentrate					5138.85	5049.05	4861.00	1544.26
	Barite Values in Tailing					52.36	142.16	330.21	3646.95
Results	Cumulative Weight of Concentrate, %					65.88	57.21	54.53	16.30
	Cumulative Weight of Tailing, %					34.12	42.79	45.47	83.70
Float/Sink	Concentrate Grade, $BaSO_4$ %					78.00	88.25	89.14	94.74
	Tailing Grade, $BaSO_4$ %					1.53	3.32	7.26	43.57
Head Basis	Barite Distribution in Concentrate					99.00	97.26	93.64	29.75
	Barite Distribution in Tailing					1.00	2.74	6.36	70.25

* Barite value of a fraction is the product of the weight percent and barite grade of the fraction.

cumulative results, assuming separation specific gravities of 4.27, 3.49, 3.23 and 2.95.

While Table 12 contains the dense liquid separation results for the float and sink head sample, similar results are shown in Table 13 for the total head sample by assuming that the finer than 200 mesh material is not separated, but directly joins the tailings product.

6.1 Discussion of Dense Liquid Separation Test Results

The dense liquid separation test results relate to ideal separation conditions and, therefore, they are the best possible results obtainable. A good practical separation in a mineral processing plant may approach these results, but cannot equal them. It should be remembered that the following discussion refers to the ideal separation.

Table 7 gives the size analysis and barite distribution figures for both the blended head sample and for the float and sink head sample. The finer than 200 mesh fraction amounted to 21.36% of the total weight and contained 11.16% of the barite values of the total feed. There was a marked gradual reduction of barite grade towards the finer size fractions and there was marked reduction in the finer than 200 mesh size fraction at 24.38% barite. Thus, it appears that rejection of the finer than 200 mesh material would not seriously affect barite recovery.

Table 9 contains the specific gravities of float and sink fractions produced at the various specific gravity separations. From this table it appears that a good density separation should be able to give a concentrate of at least 4.2 specific gravity mud grade barite at a separation specific gravity of 3.3 to 3.4. The grades of size fractions calculated from the specific gravity fractions are slightly different from the grades given in Table 7, but these differences may be explained by sampling errors.

TABLE 13

Cumulative Results for the Blended Head Sample, Assuming that the Finer Than 200 Mesh Material Joins the Tailings Product

		2.95 S.G.	3.23 S.G.	3.49 S.G.	4.27 S.G.
Cumulative Results Blended Head Sample	Barite Values* in Concentrate	4234.39	4160.39	4005.44	1272.46
	Barite Values in Tailing	563.90	637.90	792.85	3525.83
	Cumulative Weight of Concentrate, %	54.28	47.14	44.93	13.43
	Cumulative Weight of Tailing, %	45.72	52.86	55.07	86.57
	Concentrate Grade, $BaSO_4$ %	78.00	88.25	80.14	94.74
	Tailing Grade, $BaSO_4$ %	12.33	12.07	14.40	40.73
	Barite Distribution in Concentrate	88.25	86.71	83.48	26.52
	Barite Distribution in Tailing	11.75	13.29	16.52	73.48

* Barite value of a fraction is the product of the weight percent and barite grade.

Table 10 contains the weight percentages of size fractions as they would appear in a sequential float and sink analysis. What is not prominent in this table is that the weight percentage variations of size fractions against specific gravity are markedly different. As Figure 1 shows the coarser fractions contain more higher grade barite than the finer fractions, except above 4.1 specific gravity. Over about 4.1 the graphs indicate lower degrees of liberation for the coarser fraction and higher for the finer.

Observing the barite distributions given in Table 10, it is apparent that the float and sink head sample is substantially liberated as 92.40 to 95.61% barite distributions appear in the 3.49 specific gravity sink products.

Table 11 shows the weight percentages expressed on the float and sink head basis. From this table, one can see that the 6-18 mesh size fraction contains 47.23 weight percent of the float and sink head sample and 38.92 weight percent of the blended feed. Other size fractions constitute much lower weight percentages.

The cumulative results of float and sink separation expressed on float and sink head basis are calculated in Table 12. The results show that for an ideal separation at 3.23 specific gravity, 57.21 weight percent of the feed reports to the concentrate whose grade is 88.25% barite with a recovery of 97.26%. From the measured specific gravities of sink products (Table 9) and from the weight percentages of size fractions, the calculated specific gravity of this concentrate is 4.17. This is lower than required for mud grade barite.

At an ideal separation of 3.49 specific gravity, 54.53% of the feed reports to the concentrate whose grade is now 89.14% with 93.64% of

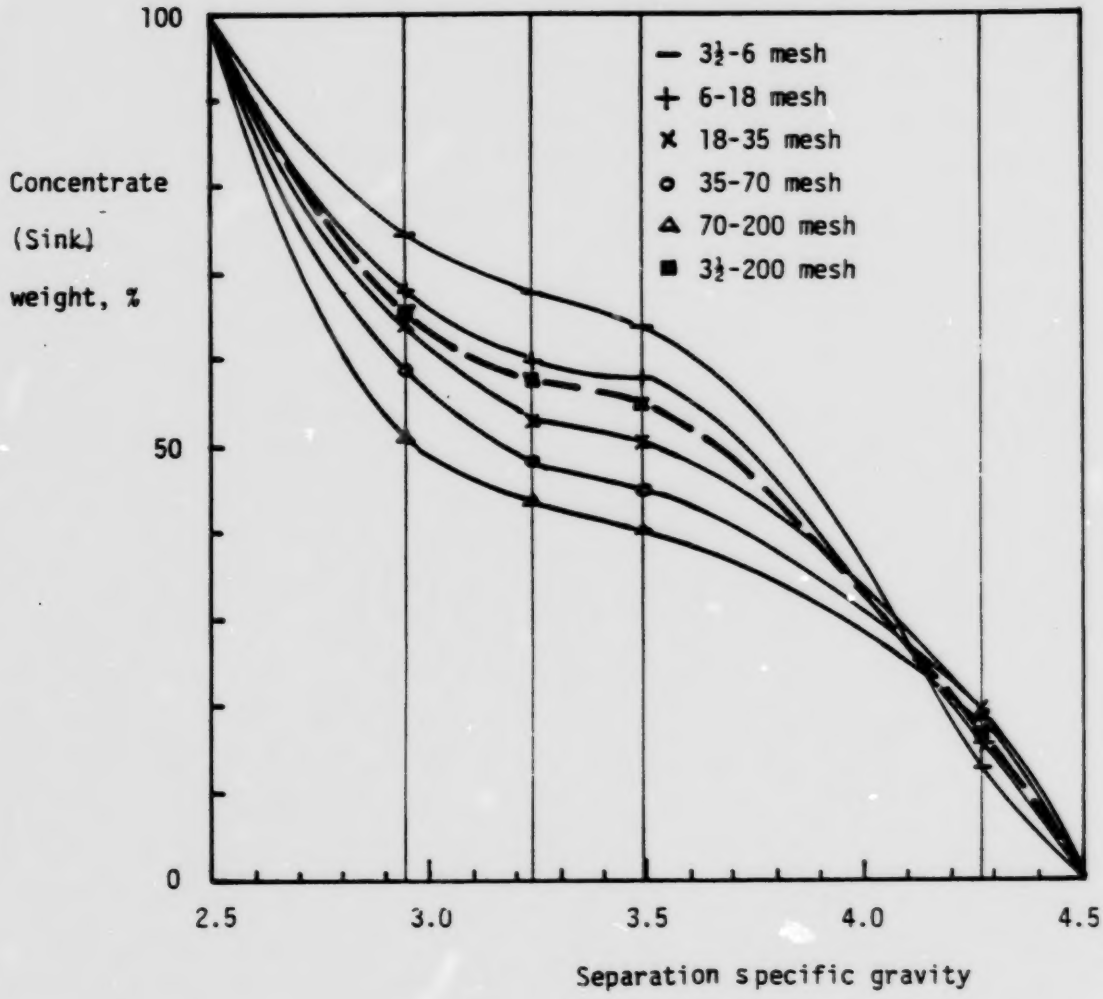


Figure 3. Concentrate Weight Distributions of Size Fractions Against Separation Specific Gravity

the barite recovered. The concentrate has a specific gravity of 4.29 calculated as before.

The concentrate grade, tailings grade and barite recovery variation with concentrate mass percent are shown in Figure 4. The recovery graph is almost a straight line up to 97% recovery with a sharp bend following this point, again indicating reasonable barite liberation. The perfect recovery curve, which is possible at 100% degree of liberation is shown as a broken line.

The concentrate grade versus recovery and the concentrate grade versus specific gravity of separation graphs are shown in Figure 5. From the first graph it is evident that the concentrate grade is slowly decreasing up to about 95% recovery, after which there is a sudden reduction. This points to a reasonably good degree of liberation of the barite. From the grade versus specific gravity of separation one can see that a 3.4 specific gravity of separation would ideally give 89% concentrate grade. However, the concentrate grade against specific gravity graph is very flat, between 3.2 and 3.7, indicating that slight variations in the specific gravity of separation would have little effect on the grade of concentrate.

The ideal separation results for the blended head sample are given in Table 13. Here it is assumed that the finer than 200 mesh material is rejected to the tailing. Assuming an ideal separation at 3.23 specific gravity, 47.14% of the feed would appear in the concentrate. The grade of concentrate is 88.25%, the same as before, but the tailings grade has increased from 3.32% to 12.07%. The barite recovery has dropped from 97.26% to 86.71%.

For an assumed 3.49 specific gravity separation, 44.93% of the feed reports to the concentrate whose grade is 89.14%. The tailings grade has increased from 7.26% to 14.40% and the recovery has fallen from 93.64% to 83.48%.

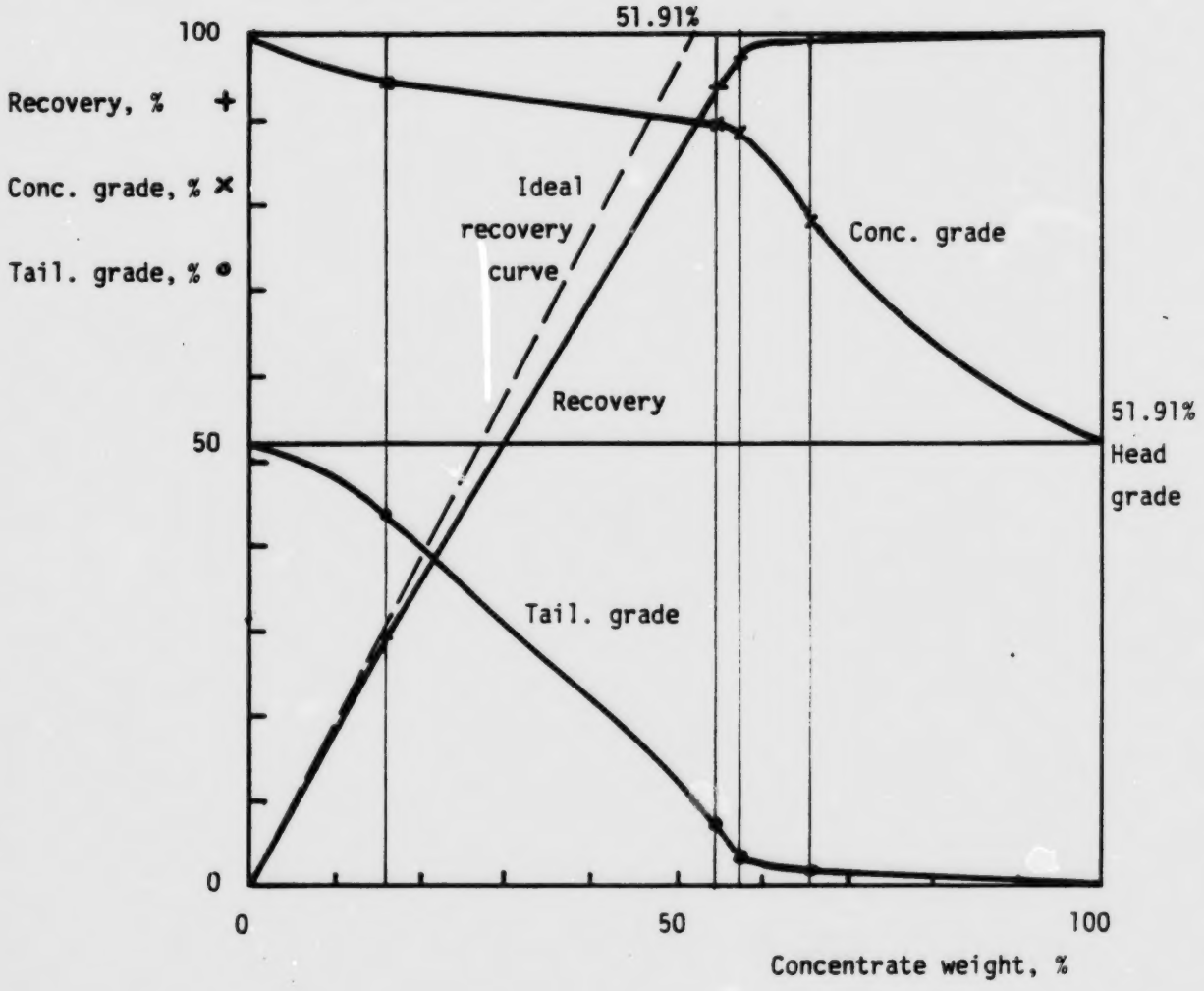


Figure 4. Concentrate Grade, Tailings Grade and Recovery Against Concentrate Weight Percent as obtained from Dense Liquid Separation of Float/Sink Head Sample

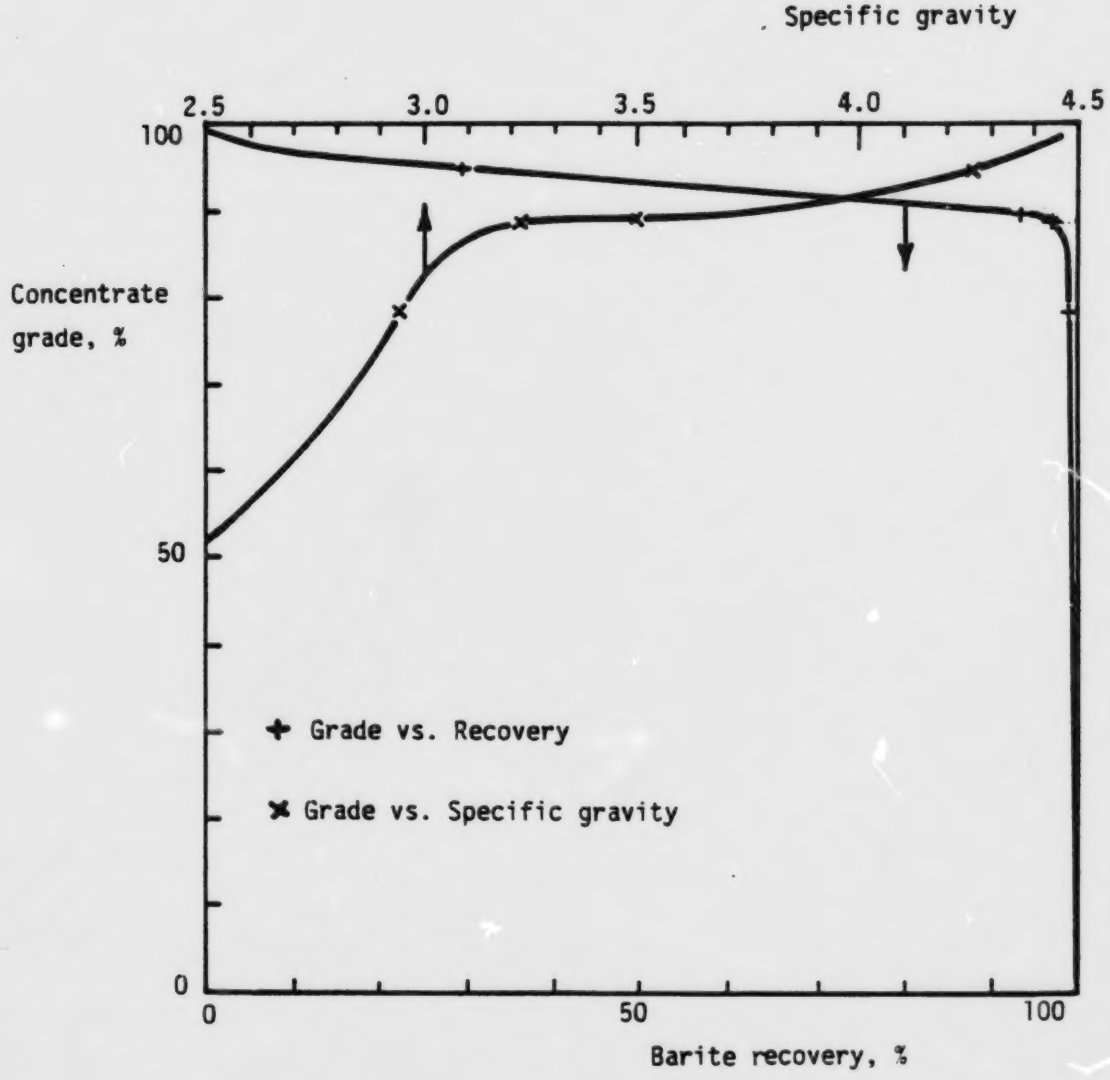


Figure 5. Concentrate Grade Versus Recovery and Concentrate Grade Versus Specific Gravity of Separation for Float/Sink Head Sample

Analyzing the dense-liquid separation one may conclude that a mud grade barite concentrate can be produced from the ore when it is crushed finer than 3.5 mesh as long as the concentrator is able to achieve a sharp separation. The concentration process is aided by the removal of the finer than 200 mesh portion of the feed without sacrificing recovery.

PHASE III

7. TRI-FLO SEPARATOR TESTS

Tri-Flo separator tests were carried out by Lakefield Research, Ontario, on a screened ore sample of approximately 120 kg supplied by the Minerals Engineering Centre. The size range of this sample was 3.5 to 35 mesh. To reduce media contamination with fines, Lakefield Research rescreened the sample at 30 mesh.

A copy of the Report received from Lakefield Research is attached as Appendix A.

7.1 Discussion of Tri-Flo Separation Test Results

The barite recovery* against the concentrate weight percent has been replotted from the results tabulated in the Report, Appendix A, pages 11 and 12. On this plot (Figure 6) the ideal recovery curve is also shown as a broken line. The ideal recovery should reach the mineral content of the feed at the 100% recovery level. This point, as calculated from the results shown in Table 7, taking into account that the Tri-Flo separation feed ranged from 3.5 to 30 mesh, is 55.10%, very close to the feed assay results obtained by Lakefield Research as 54.23% (31.9% Ba). The recovery curve expected from dense liquid analysis on the Tri-Flo separation sample has also been calculated from Tables 11 and 12 and plotted in Figure 6. This curve shows the optimum recovery obtainable at this degree of barite liberation.

Considering the grade recovery and the specific gravity recovery relationships of Appendix A, page 8, one concludes that mud grade

* In this report, recovery refers to the barite distribution in the concentrate and the grades of feed, concentrate and tailing are expressed as $BaSO_4$ percentages of the respective products. The concentrate weight percent is the percentage of feed reporting to the concentrate.

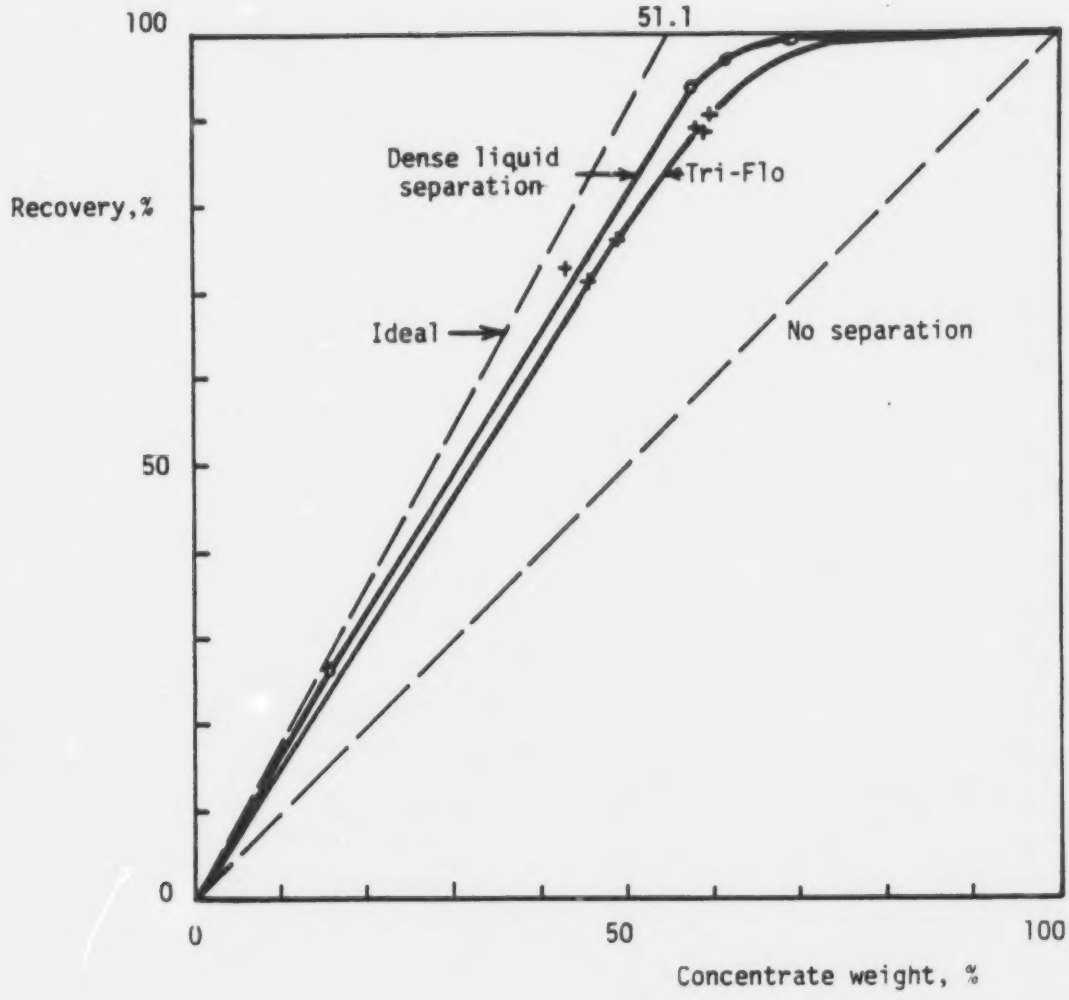


Figure 6. Comparison of Recovery Curves for Tri-Flo and Dense Liquid Separations

barite of 4.2 specific gravity could be produced at this feed size range with about 75% barite recovery. The barite grade of this concentrate appears to be 85% (50% Ba) which seems somewhat low for the 4.2 specific gravity.

Relating the separation of Test 4 to the 3.5 - 200 mesh feed, the Tri-Flo separation would recover approximately 39 weight percent at a barite recovery of approximately 62%. When considering the total blended feed, 3.5 mesh to 0, about 30% of the feed would go to the concentrate with a recovery of about 55%. Therefore, if a dense medium separation was considered for the concentration of the Pine Brook barite, an alternative treatment for the fines would be necessary, resulting in a more complex plant flow sheet.

8. JIGGING TESTS

The jigging tests were carried out on samples of the 3 1/2 mesh to 0 blended head sample, grading 46.64% barite. A Denver Mineral Jig with a 4 in. by 6 in. screen area was used. The slot size of the grating was approximately 6 mm. The jig was fed from an Eriez Vibrating Feeder. In the first series of tests eight runs were made at 4.11 kg/min solids feed rate. In tests 1 and 2, 1/4 in. to 1/2 inch high grade barite was used as ragging. For tests 3 to 8, 1490 g of 11.2 mm steel balls were used for ragging. Samples of concentrate and tailings were collected for a 30 second period. The water flow rate and the stroke of the jig diaphragm were varied during the eight tests. The dry weights of products were determined together with their specific gravities. These test results are shown in Table 14.

Another series of twenty seven runs was made in which 1/4 in. to 1/2 in. high-grade barite was used as ragging at three different bed heights. These tests were carried out at full stroke length and three levels of solids feed rates and three levels of water flow rates. The test results for these runs are given in Table 15.

TABLE 14

Test Results on Jigging 3 1/2 mesh to 0
Pine Brook Barite Blended Feed
(Tests 1 to 8)

TEST RESULTS						
Test No.	Stroke	Water L/min	Weight, g		Specific Gravity	
			Conc.	Tails	Conc.	Tails
1	Full	38.4	1561	3096	4.25	3.30
2	3/4	38.4	3156	2051	3.80	3.14
3	Full	38.4	343	2005	4.01	3.21
4	Full	19.2	382	1500	4.02	3.16
5	3/4	38.4	406	1680	4.07	3.18
6	3/4	19.2	615	1375	3.97	3.42
7	9/16	38.4	249	1704	4.22	3.21
8	9/16	19.2	85	1254	3.97	3.28

8.1 Discussion of Jigging Test Results

The calculated results of jigging tests 1 to 8 appear in Table 16. From the product weights, the weight percentages were calculated. The barite grades of products were calculated from their measured specific gravities, assuming the specific gravity of barite to be 4.5 and that of the gangue to be 2.65. The reconstituted head grade was calculated from the product weight percentages and grades. The distribution was calculated on the basis of the reconstituted head grade.

The concentrate grade ($BaSO_4$%), tailings grade ($BaSO_4$%) and recovery are plotted against the concentrate weight percent in Figure 7. The concentrate grade against recovery is shown in Figure 8.

TABLE 15

Test Results on Jigging 3 1/2 mesh to 0 Pine Brook Barite Blended Feed at Full Stroke.

Tests 9 to 17 used 783 g of 1/2 in. to 1/4 in. high grade barite ragging (2.3 cm bed height)
Tests 18 to 26 used 490 g of 1/2 in. to 1/4 in. high grade barite ragging (1.4 cm bed height)
Tests 27 to 35 used 293 g of 1/2 in. to 1/4 in. high grade barite ragging (0.85 cm bed height).

TEST RESULTS						
Test No.	Solids Feed Rate, kg/min.	Water Flow Rate, L/min	Weight, g		Specific Gravity	
			Conc.	Tails	Conc.	Tails
9	2.01	42	224	1696	4.31	3.20
10	2.01	25	308	1462	4.28	3.11
11	2.01	18	327	1330	4.23	3.10
12	3.01	18	338	2410	4.22	3.20
13	3.01	26	262	2622	4.30	3.19
14	3.01	42	222	2176	4.29	3.19
15	4.19	42	240	3946	4.29	3.30
16	4.19	26	282	3866	4.34	3.28
17	4.19	18	376	4014	4.33	3.50
18	1.99	42	423	1319	4.21	3.15
19	1.99	26	492	1105	4.21	3.14
20	1.99	18	592	1193	4.21	3.06
21	3.10	18	636	1400	4.21	3.08
22	3.10	25	572	1964	4.21	3.09
23	3.10	42	430	1998	4.24	3.15
24	3.95	42	466	3200	4.23	3.15
25	3.95	26	586	3030	4.22	3.15
26	3.95	18	646	2786	4.20	3.19
27	3.95	18	1358	2458	4.08	3.10
28	3.95	26	980	3390	4.21	3.15
29	3.95	42	768	4070	4.22	3.22
30	3.12	42	782	2370	4.20	3.18
31	3.12	25	862	1840	4.21	3.12
32	3.12	18	1500	1882	4.18	3.08
33	2.17	18	994	1112	4.18	3.14
34	2.17	24	818	1150	4.18	3.11
35	2.17	42	650	1930	4.20	3.14

TABLE 16

Calculated Results of Jigging Tests 1 to 8

CALCULATED							
Test No.	Weight, %		$BaSO_4$, %			Distribution, %	
	Conc.	Tails	Conc.	Tails	Head	Conc.	Tails
1	33.52	66.48	91.57	47.91	62.54	49.08	50.92
2	60.61	39.39	73.61	37.96	59.57	74.90	25.10
3	14.61	85.39	82.50	42.43	48.28	24.97	75.03
4	20.30	79.70	82.90	39.26	48.12	34.97	65.03
5	19.46	80.54	84.87	40.54	49.17	33.59	66.41
6	30.90	69.10	80.88	54.77	62.84	39.77	60.23
7	12.75	87.75	90.50	42.43	48.77	23.66	76.34
8	6.35	93.65	80.88	46.72	48.89	10.50	89.50

The results in Table 16 show that tests numbers 1, 2 and 6 operated on a higher feed grade. For tests 1 and 2 this increase is explained by the use of high grade barite ragging some of which appeared in the concentrate. This effect is noticeable in Figures 7 and 8 as these points do not fit on the concentrate grade curves. For test number 6 there is no adequate explanation for the higher head grade. The slight increase of reconstituted head grades from 46.64 results from some of the very fine clayey material being suspended in water and not recovered in the products.

At the 4.11 kg/min solids feed rate of the test jig, the specific feed rate was 15.9 $t/h/m^2$. The specific water consumption amounted to 147 m^3/hm^2 at the 38.4 L/min. flow rate and 74.4 m^3/hm^2 at 19.2 L/min.

Only two of the jigging tests gave the concentrate specific gravities over 4.2 as required for mud grade barite. Test number 1 should not be considered, since its head grade was inflated by the high grade barite ragging leaking into the concentrator. The concentrate of test number 7 is above the required grade. However, this is at the cost of a very low barite recovery of 23.66 %, which would not be acceptable in practice.

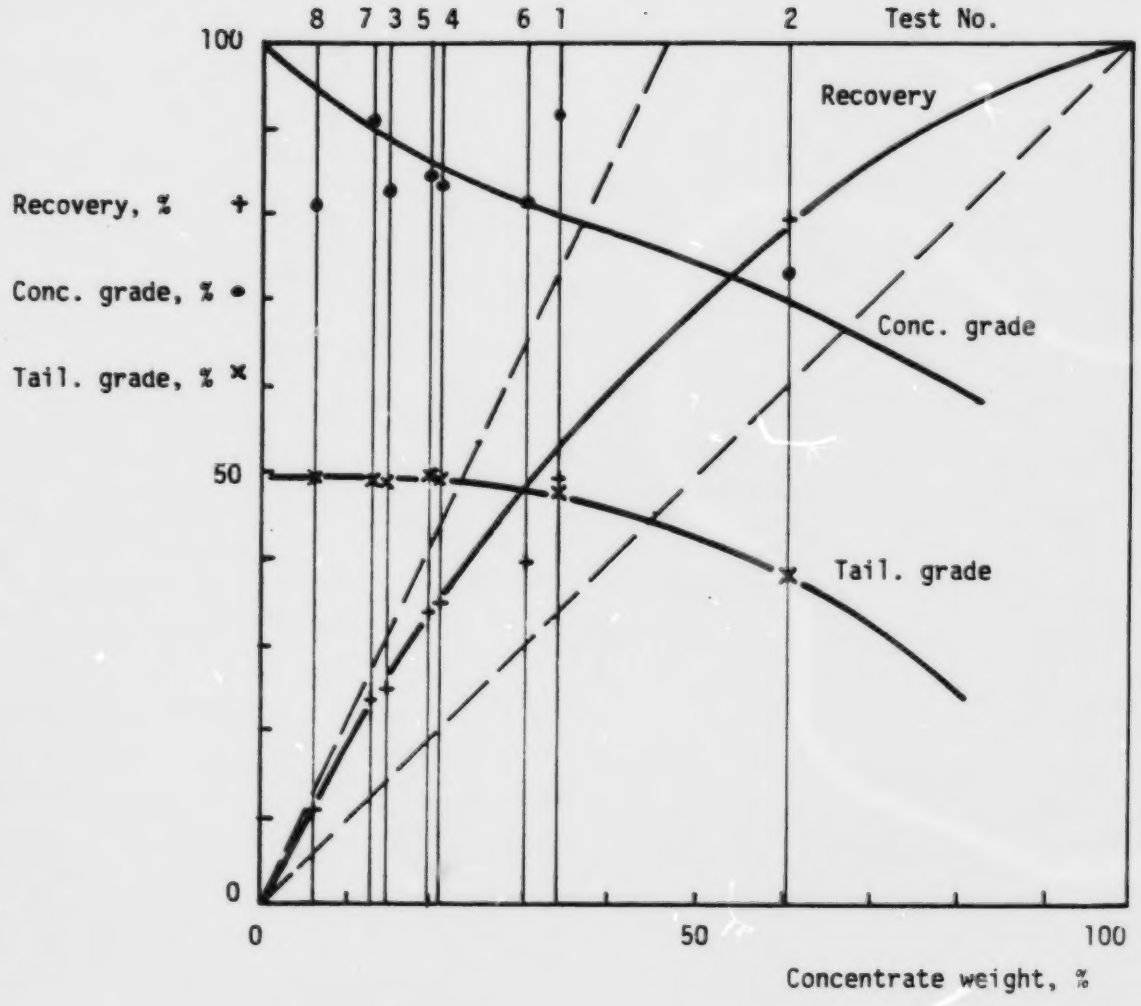


Figure 7. Concentrate Grade, Tailing Grade and Recovery Against Concentrate Weight Percent as Obtained from Jigging Tests, 1 to 8

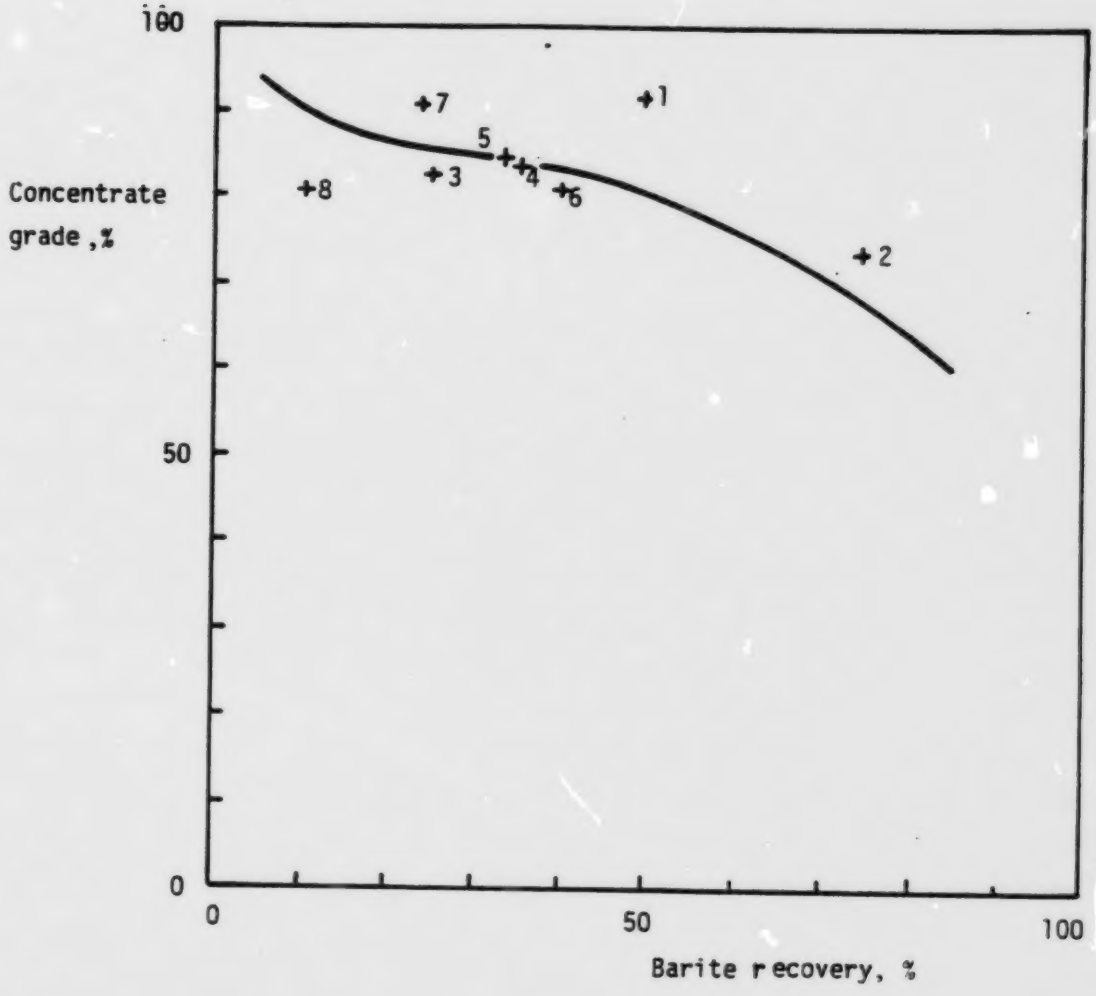


Figure 8. Concentrate Grade Versus Recovery Obtained in Jigging Tests, 1 to 8

The calculated results of jigging tests 9 to 35 appear in Table 17. The weight percentages of concentrates and tailings were calculated from their respective weights. The barite grades of products were calculated from their measured specific gravities as before. The reconstituted head grade was calculated from the product weight percentages and grades. The distributions are expressed on the basis of the reconstituted head grade.

The 2.01, 3.01 and 4.19 kg/min solids feed rate of the test jig amounted to specific feed rates of 7.78, 11.65 and 16.2 $t/h/m^2$. The specific water consumptions at 18, 25 and 42 L/min for the test jig were 69.7, 96.8 and 163 $m^3/h/m^2$.

These results indicate that with careful choice of operating variables jigging can give the required grades with reasonable barite distributions. Barite recovery is greater with shallower beds of ragging and at lower water flow rates, since these conditions allow more barite particles to penetrate the ragging and to report to the concentrate. Good examples are tests 32 and 33. This observation emphasises the importance of the correct choice for density and depth of ragging.

The recovery against concentrate weight percent for selected tests is shown in Figure 9. A barite recovery of 60% is obtainable at mud-grade as tests below this level give higher than 4.2 specific gravity, while tests above are slightly below 4.2.

The concentrate grade versus barite recovery is shown for selected jigging tests in Figure 10. Since 4.2 specific gravity is equivalent to approximately 90% barite content, this graph also indicates that 60% recovery is a practical possibility.

TABLE 17

Calculated Results on Jigging 3 1/2 mesh to 0 Pine Brook Barite Blended Feed at Full Stroke

Tests 9 to 17 used 783 g of 1/2 in. to 1/4 in. high grade barite ragging (2.3 cm bed height)
Tests 18 to 26 used 490 g of 1/2 in. to 1/4 in. high grade barite ragging (1.4 cm bed height)
Tests 27 to 35 used 293 g of 1/2 in. to 1/4 in. high grade barite ragging (0.85 cm bed height).

Test No.	Weight, %		$BaSO_4$, %			Specific Gravity Head	Barite Distribution, %	
	Conc.	Tails.	Conc.	Tails.	Head		Conc.	Tails
9	11.67	88.33	93.7	41.8	47.9	3.30	22.8	77.2
10	17.40	82.60	92.6	36.0	45.8	3.27	35.1	64.9
11	24.59	75.11	90.9	35.3	48.9	3.33	45.7	54.3
12	12.30	87.70	90.5	41.8	47.9	3.30	23.3	76.7
13	9.99	90.01	93.3	41.2	46.1	3.27	20.1	79.9
14	9.26	91.74	93.0	41.2	43.7	3.23	18.6	81.4
15	5.73	94.27	93.0	47.9	50.2	3.34	10.6	89.4
16	6.80	93.20	94.7	46.7	50.2	3.34	12.9	87.1
17	8.57	91.43	94.4	59.1	62.2	3.56	13.0	87.0
18	24.28	75.72	90.1	38.6	51.4	3.36	42.8	57.2
19	30.81	69.19	90.1	38.0	54.2	3.41	51.4	48.6
20	33.02	66.98	90.1	32.6	51.4	3.36	57.7	42.3
21	31.24	68.76	90.1	34.0	51.4	3.36	54.6	45.4
22	22.56	77.44	90.1	34.6	47.3	3.29	43.1	56.9
23	17.71	82.29	91.2	38.6	47.9	3.30	33.7	66.3
24	12.71	87.29	90.9	38.6	45.5	3.26	25.5	74.5
25	16.21	83.79	90.5	38.6	47.3	3.29	31.2	68.8
26	23.19	76.81	89.8	41.2	52.5	3.38	39.7	60.3
27	35.59	64.41	85.3	35.3	53.1	3.39	57.2	42.8
28	24.43	77.57	90.1	38.6	47.3	3.29	42.4	57.6
29	15.87	84.13	90.5	43.1	50.8	3.35	28.4	71.6
30	24.81	75.19	89.8	40.5	52.5	3.38	42.3	57.7
31	31.90	68.10	90.1	36.6	53.7	3.40	53.6	46.4
32	44.35	55.65	89.0	34.0	58.5	3.49	67.6	32.4
33	47.20	52.80	89.0	38.0	62.2	3.56	67.7	32.3
34	41.57	58.43	89.0	36.0	58.0	3.48	63.8	36.2
35	25.19	74.81	89.8	38.0	59.1	3.50	44.3	55.7

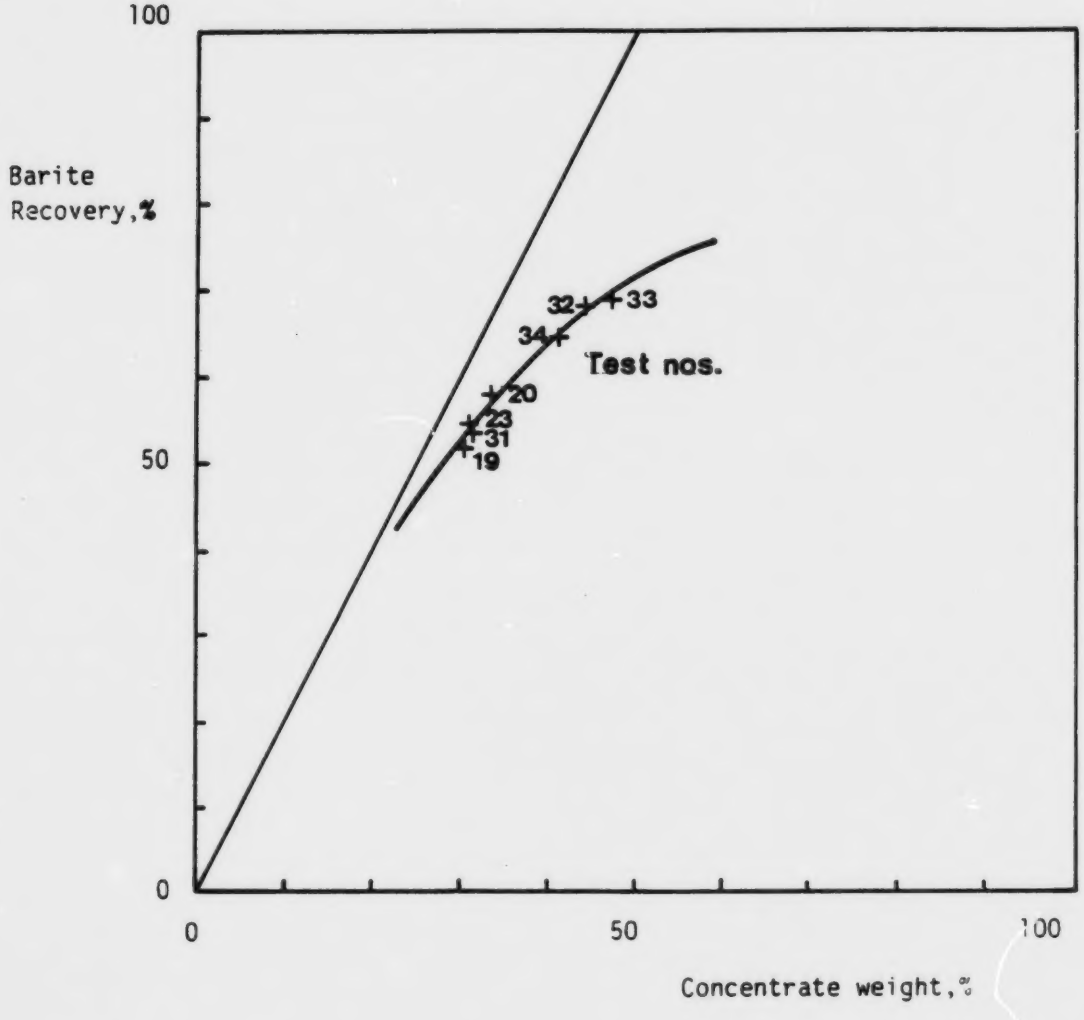


Figure 9. Barite Recovery Against Concentrate Weight Percent as Obtained in Selected Jigging Tests

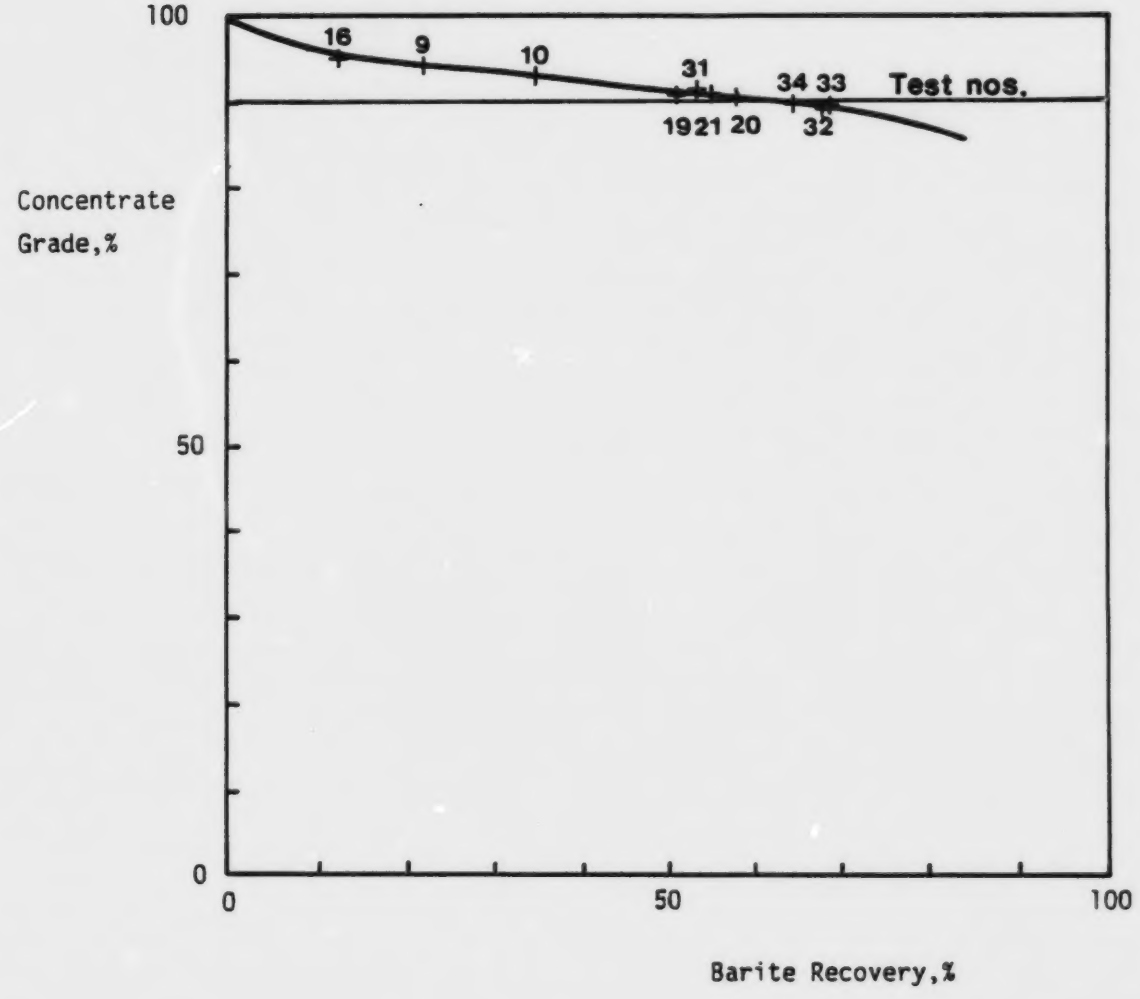


Figure 10. Concentrate Grade Versus Barite Recovery for Selected Jigging Tests

The sharp change in barite recovery with specific gravity of concentrate is shown in Figure 11. Thus, in a plant concentrating by jigging, care must be taken to keep the concentrate specific gravity (or barite grade) as close as possible to the required, so that the barite recovery will be maximized.

The jigging test results show that mud-grade barite can be produced from 3 1/2 mesh to 0 Pine Brook Barite feed at 60% barite recovery.

9. HUMPHREYS SPIRAL TESTS

Humphreys Spiral tests were carried out on finer than 1 mm and finer than 0.5 mm. blended head samples. The test circuit is shown in Figure 12. The solids and water were mixed in the pump sump. A 4 in diameter hydrocyclone was included in the spiral feed pulp circuit to remove the same amount of water as the wash water applied and thus to maintain a reasonably constant pulp solids concentration. Of course, it was inevitable that the cyclone continuously removed some fines from the circuit.

The spiral was run at various wash water flow rates. Samples of concentrate, tailing and cyclone overflow were collected for timed periods. These samples were weighed, filtered and dried and the dry weights of solids and their specific gravities determined. The Humphreys Spiral test results are shown in Table 18.

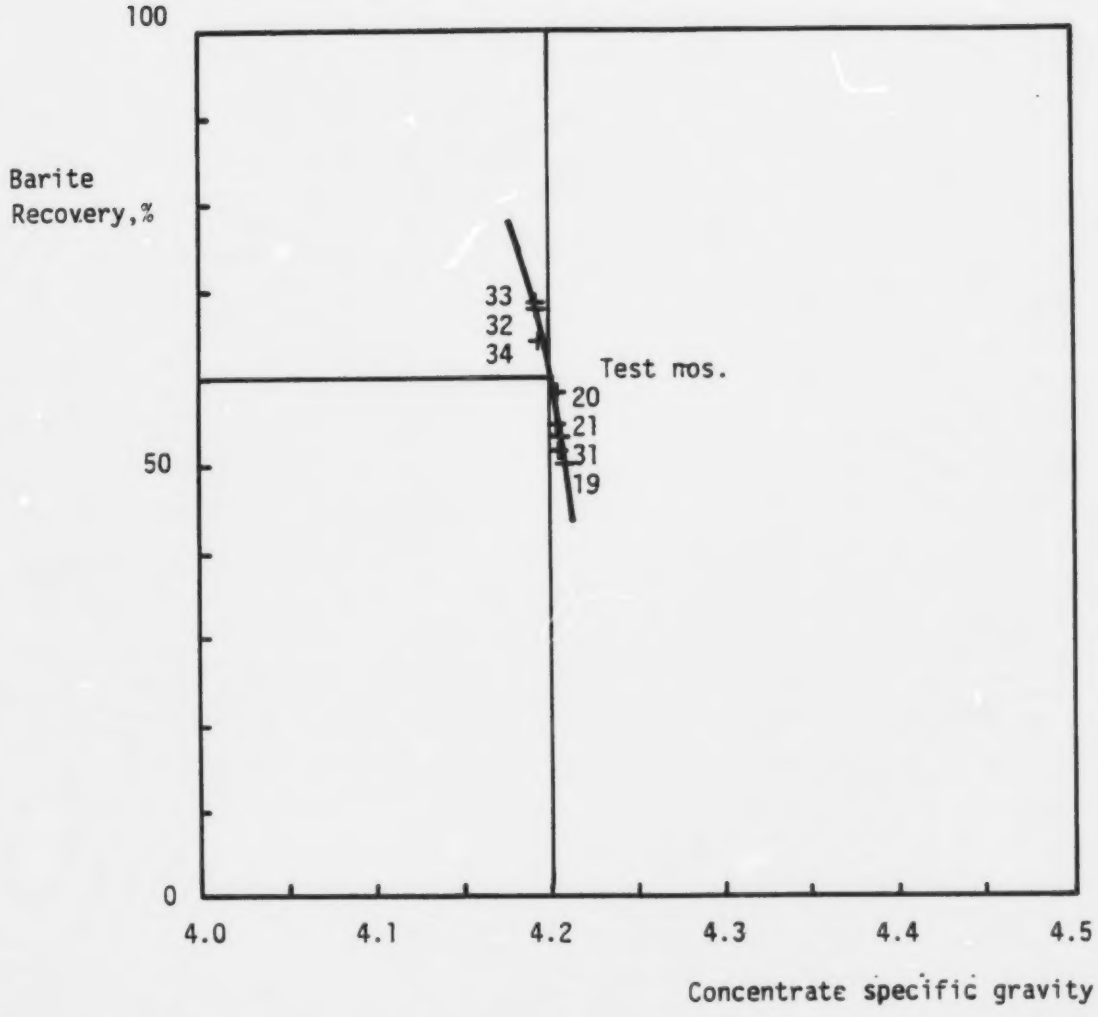


Figure 11. Barite Recovery Against Concentrate Specific Gravity for Selected Jigging Tests

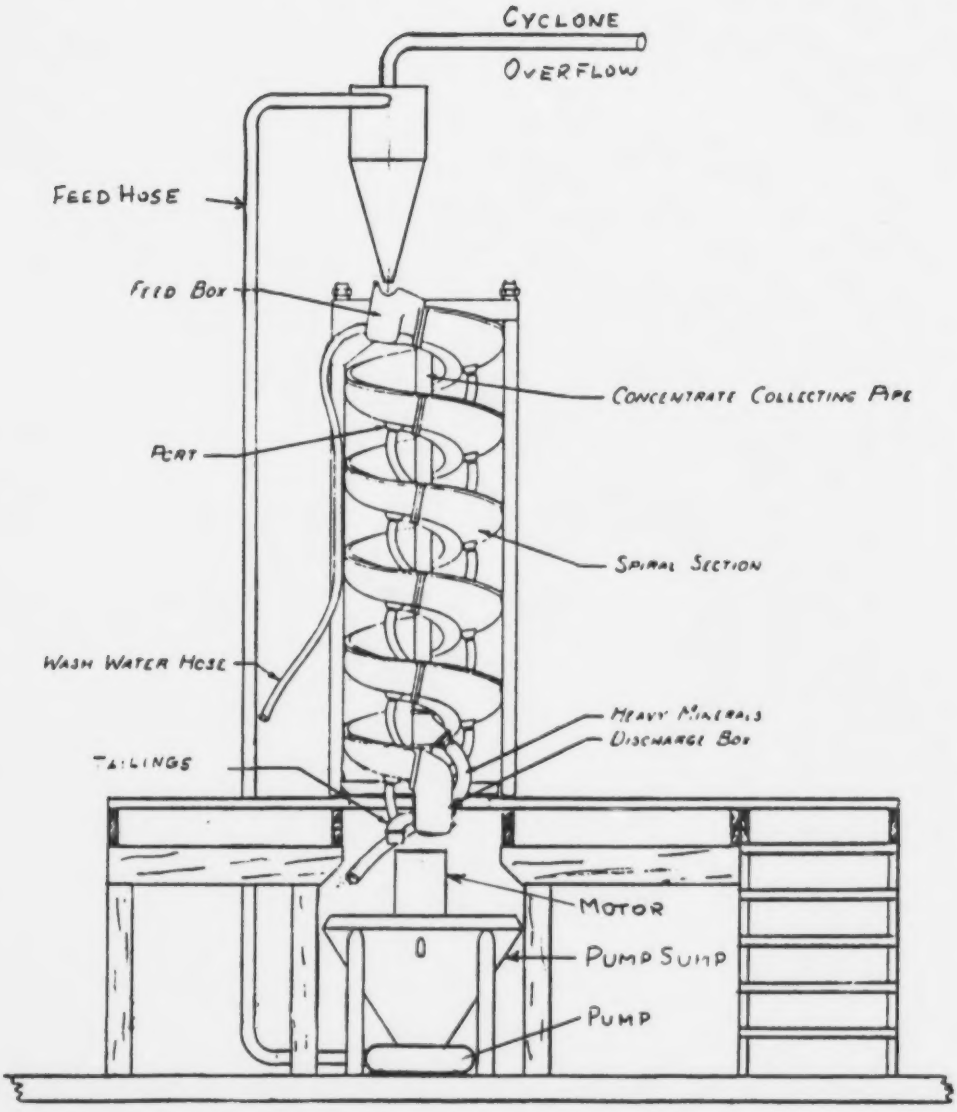


Figure 12. The Humphreys Spiral Test Circuit

TABLE 18

Humphreys Spiral Test Results

TEST RESULTS							
Test No.	Wash Water L/min.	Specific Gravity			$BaSO_4$, %		
		Conc.	Tails.	Cyc. O/F	Conc.	Tails.	Cyc. O/F
1	24.0	4.09	3.21	3.15	82.7	37.08	31.3
2	10.8	4.07	3.21	3.14	80.6	35.3	29.4
3	10.8	3.99	3.28	3.15	82.4	42.5	31.9
4	32.4	4.12	3.35	3.14	86.8	50.8	38.0
5	13.2	3.85	3.51	3.36	75.8	59.6	51.4
6	-	4.18	3.33	3.33*	89.0	49.7	49.7*

* Test no. 6 used a Reichert Mark 7LG spiral. Figures in the cyclone O/F columns refer to the spiral middling product.

The size distribution of feed was determined for tests nos. 4 and 5 as given in Table 19.

TABLE 19

Size Distribution of Feed for Tests Nos. 4 and 5

Size Range, Mesh	Weight %	
	Test No. 4	Test No. 5
+ 18	5.1	-
18 to 35	23.9	-
35 to 70	20.0	5.5
70 to 200	14.3	35.0
- 200	36.7	59.5

The calculated results for Humphreys Spiral Tests are given in Table 20.

The concentrate grade variation against barite recovery for spiral concentrator tests is shown in Figure 13.

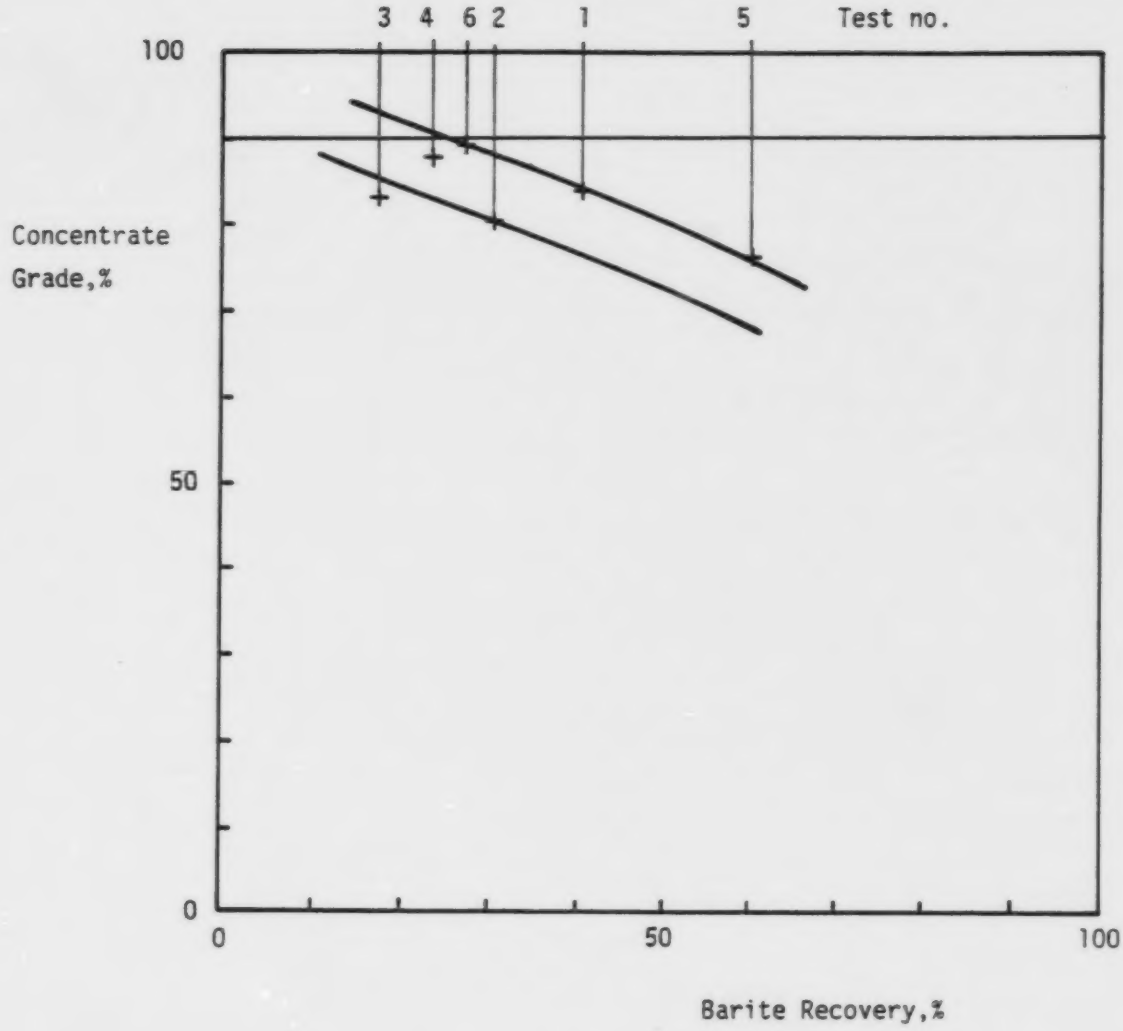


Figure 13. Concentrate Grade Against Barite Recovery for Spiral Concentrator Tests

9.1 Discussion of Humphreys Spiral Concentrator Test Results

The weight percentages of concentrates, tailings and cyclone overflows were calculated from the dry weights of products. From the weight percentages and the barite grades, the barite distributions for concentrate, tailing and cyclone overflow were calculated, based on the reconstituted head grade. The total water consumption in m^3/h and solids feed rate in t/h per start of spiral were determined. These results are given in Table 20. The Humphreys Spiral test results are also shown in graphical form in Figure 13.

As seen in Tables 18 and 20, the concentrates produced by the Humphreys Spiral do not satisfy the requirements for mud grade barite and, even at the relatively low grades of concentrates, the barite recoveries are too low. It was observed that the conditions could not be set correctly for both fine and coarse barite particles. A spiral concentrator would give better separation results when operated with a classified feed. However, hydraulic classification is a low capacity and costly operation and is unlikely to be economically justified.

Apart from the Humphreys Spiral Tests, a Reichert spiral, Mark 7LG was also used in test no. 6. This spiral is very easy to operate in closed circuit since it requires no wash water. With this spiral, three products, concentrate, middlings and tailings were obtained. The concentrate specific gravity was 4.18, but the barite recovery was only 27.5%.

The test results obtained show that spiral concentration fails to give adequate grade and recovery and therefore should not be considered as a possible method of concentration for the Pine Brook Barite ore.

TABLE 20

Calculated Results for Humphreys Spiral Tests

C A L C U L A T E D									
Test No.	Weight, %			Head Grade, $BaSO_4$, %	Barite Distribution, %			Water Cons. m^3/h	Solids Feed t/d
	Conc.	Tails.	Cyclone O/F		Conc.	Tails.	Cyclone O/F		
1	23.7	71.5	4.8	47.6	41.3	55.6	3.1	7.1	0.36
2	16.5	70.3	13.2	42.0	31.7	59.1	9.2	5.3	0.16
3	10.0	82.4	7.66	45.6	18.0	76.7	5.3	5.5	0.19
4	15.3	83.2	1.5	56.1	23.7	75.3	1.0	6.4	0.21
5	54.8	38.7	6.5	67.9	61.1	34.0	4.9	5.9	0.11
6*	17.5	69.0	13.5	56.6	27.5	60.6	11.9	-	-

* Test No. 6 used a Reichert Mark 7LG spiral. In this test the aim was to recover as much concentrate as possible. No timed sample was taken.

10. SHAKING TABLING TESTS

Shaking table tests were carried out on a Wilfley Laboratory Concentrating Table, Type 13B, with deck dimensions of 1270 mm x 610 mm. Two decks were used; a fines/slimes deck with shallow riffles parallel to the longitudional axis and a sands deck with medium height riffles angled towards the top discharge end of the deck. The feeds for these tests were prepared from samples of the 3 1/2 mesh to 0 blended head sample by grinding for set periods in a laboratory rod mill. The two feed distributions used were finer than 1 mm and finer than 0.5 mm. The main operating variables examined were solids feed rate, water flow rate, transversal deck slope, stroke length and frequency of reciprocation.

The results of the shaking table tests are given in Tables 21 to 25.

Shaking tabling test No. 7 was carried out on a deslimed feed to evaluate the effect of the presence of slimes in the feed. A 4 in. diameter hydrocyclone was fed with the finer than 0.5 mm blended feed at 14.3% solids by weight. The desliming results are shown in Table 26.

The shaking table test results are also given in graphical form. The barite recovery against concentrate weight percent is shown in Figures 14, 15 and 16, while the concentrate grade against barite recovery is shown in Figure 17, 18 and 19.

TABLE 21

Results of Shaking Table Tests 1 and 2

Test No.	Operating Conditions	Sample	Weight %	S.G.	$BaSO_4$ %	Barite Value	Cum. Barite Value	Cum. Weight %	Cum. Grade %	Cum. Barite Dist., %
1	Fines deck Minus 1 mm feed 1.4 kg/min. feed rate 13.2 L/min. total water 1 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 525/min frequency	Conc.	5.9	4.34	94.7	556	556	5.9	94.7	11.5
		Mid. 1	12.5	4.07	84.9	1057	1613	18.4	88.0	33.5
		Mid. 2	12.4	3.78	72.2	905	2518	30.8	81.8	52.3
		Mid. 3	9.5	3.19	41.2	392	2910	40.3	72.2	60.4
		Tail.	59.7	3.05	31.9	1905	4815	100.0	48.2	100.00
			100.0		48.15	4815				
2	Fines deck Minus 1 mm feed 1.4 kg/min feed rate 18.2 L/min total water 1 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 525/min frequency	Cons.	5.8	4.37	95.7	553	553	5.8	95.7	11.1
		Mid. 1	16.1	4.18	89.0	1428	1981	21.9	90.8	39.6
		Mid. 2	12.6	3.87	76.7	965	2946	34.5	85.6	58.9
		Mid. 3	15.1	3.12	36.6	555	3501	49.6	70.6	70.0
		Tail.	50.4	3.02	29.8	1503	5004	100.0	50.0	100.0
			100.0		50.0	5004				

TABLE 22

Results of Shaking Table Tests 3 and 4

Test No.	Operating Conditions	Sample	Weight %	S.G.	$BaSO_4$ %	Barite Value	Cum. Barite Value	Cum. Weight %	Cum. Grade %	Cum. Barite Dist., %
3	Fines deck Minus 0.5 mm feed 1.4 kg/min. feed rate 16.0 L/min. total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 525/min frequency	Conc.	10.7	4.44	98.1	1052	1052	10.7	98.1	19.4
		Mid. 1	12.0	4.23	90.9	1093	2145	22.7	94.3	39.6
		Mid. 2	19.6	3.66	67.1	1314	3459	42.3	81.7	63.9
		Mid. 3	11.8	3.00	28.4	336	3795	54.1	68.8	70.1
		Tail.	45.9	3.10	35.3	1618	5413	100.0	54.1	100.00
			100.0		54.1	5413				
4	Fines deck Minus 0.5 mm feed 2.4 kg/min feed rate 31.6 L/min total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 500/min frequency Mid. 3 was recycled to head	Cons.	2.7	4.40	96.7	262	262	2.7	96.7	4.7
		Mid. 1	2.6	4.38	96.1	250	512	5.3	96.4	9.2
		Mid. 2	7.0	4.22	90.5	637	1149	12.3	93.0	20.7
		Mid. 3	14.8	3.55	61.7	915	2164	27.1	75.9	37.2
		Mid. 4	20.5	3.61	64.7	1327	3391	47.6	71.1	61.1
		Tail.	52.4	3.19	41.2	2155	5546	100.0	55.5	100.0
			100.0		55.5	5546				

TABLE 23

Results of Shaking Table Tests 5 and 6

Test No.	Operating Conditions	Sample	Weight %	S.G.	$BaSO_4$ %	Barite Value	Cum. Barite Value	Cum. Weight %	Cum. Grade %	Cum. Barite Dist., %
5	Fines deck Minus 0.5 mm feed 2.2 kg/min. feed rate 26.5 L/min. total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 500/min frequency Mids. 3 and 4 were dried and retabled in test no.6	Conc.	1.7	4.36	95.4	162	162	1.7	95.4	4.7
		Mid. 1	5.0	4.36	95.4	479	641	6.7	95.4	9.2
		Mid. 2	9.5	4.23	90.9	861	1502	16.2	92.8	20.7
		Mid. 3	15.5	3.81	74.1	1151	2653	31.7	83.6	37.2
		Mid. 4	13.1	3.20	41.8	546	3199	44.8	71.4	61.1
		Tail.	55.2	3.08	34.0	1877	5076	100.0	50.7	100.00
			100.0		50.7	5076				
6	Fines deck Feeds - Mids. 3 and 4 of test no. 6 at 2.5 kg/min feed rate 21.5 L/min total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 500/min frequency	Cons.	2.3	4.29	93.0	215	215	2.3	93.0	3.2
		Mid. 1	4.5	4.22	90.5	407	622	6.8	91.3	12.6
		Mid. 2	7.6	3.65	66.6	504	1126	14.4	78.3	29.6
		Mid. 3	9.2	3.53	60.6	559	1685	23.6	71.4	52.3
		Mid. 4	36.3	3.46	56.9	2068	3753	59.9	62.6	63.0
		Tail.	40.1	3.10	35.3	1414	5167	100.0	51.7	100.0
			100.0		51.7	5167				

TABLE 24

Results of Shaking Table Tests 7 and 8

Test No.	Operating Conditions	Sample	Weight %	S.G.	$BaSO_4$ %	Barite Value	Cum. Barite Value	Cum. Weight %	Cum. Grade %	Cum. Barite Dist., %
7	Fines deck Feed - hydrocyclone underflow 1.48 kg/min. feed rate 22.2 L/min. total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 500/min frequency	Conc.	3.76	4.47	99.0	356	356	3.6	99.9	6.6
		Mid. 1	7.8	4.42	97.4	760	1116	11.4	97.9	20.8
		Mid. 2	14.2	4.20	89.8	1275	2391	25.6	93.4	44.6
		Mid. 3	14.8	3.65	66.6	986	3377	40.4	83.6	62.9
		Mid. 4	29.4	3.46	56.9	1673	5050	69.8	72.3	94.1
		Tail.	30.2	2.77	10.5	317	5367	100.0	53.7	100.00
			100.0		53.7	5367				
8	Fines deck Feed - Tails ground to minus 0.5 mm from jig test nos. 20,21,31,32,33 & 34 1.54 kg/min feed rate 21.8 L/min. total water 3/8 in/ft transverse slope 1/4 in/ft longit. slope 1/2 in stroke length 500/min frequency	Cons.	4.0	4.40	96.7	387	387	4.0	96.7	9.0
		Mid. 1	7.9	4.36	95.4	754	1141	11.9	95.9	26.5
		Mid. 2	6.6	3.99	81.7	539	1680	18.5	90.8	39.0
		Mid. 3	21.1	3.14	38.0	802	2482	39.6	62.7	56.6
		Mid. 4	19.1	2.86	17.9	342	2824	58.7	48.1	65.6
		Tail.	41.3	3.11	35.9	1483	4307	100.0	43.1	100.0
			100.0		43.1	4307				

TABLE 25

Results of Shaking Table Tests 9 and 10

Test No.	Operating Conditions	Sample	Weight %	S.G.	$BaSO_4$ %	Barite Value	Cum. Barite Value	Cum. Weight %	Cum. Grade %	Cum. Barite Dist., %
9	Fines deck Minus 0.5 mm feed	Conc.	4.9	4.46	98.7	484	484	4.9	98.7	9.2
	1.4 kg/min. feed rate 17.7 L/min. total water	Mid. 1	7.4	4.40	96.7	716	1200	12.3	97.6	22.8
	3/8 in/ft transverse slope 1/4 in/ft longit. slope	Mid. 2	10.4	4.16	88.3	918	2118	22.7	93.3	40.3
	3/4 in stroke length 500/min frequency	Mid. 3	20.6	3.56	62.2	1281	3399	43.3	78.5	64.6
		Mid. 4	16.0	2.95	24.7	395	3794	59.3	64.0	72.1
		Tail.	40.7	3.11	36.0	1465	5259	100.0	52.6	100.00
			100.0		52.6	5259				
10	Sands deck Minus 0.5 mm feed	Cons.	5.3	4.42	97.4	516	516	5.3	97.4	10.3
	1.4 kg/min. feed rate 16.7 L/min. total water	Mid. 1	6.5	4.38	96.1	625	1141	11.8	96.7	22.7
	5/8 in/ft. transverse slope 1/4 in/ft. longit. slope	Mid. 2	15.3	4.11	86.4	1322	2463	27.1	90.9	49.1
	3/4 in. stroke length 500/min frequency	Mid. 3	23.5	3.00	28.4	667	3130	50.6	61.9	62.4
		Mid. 4	6.7	2.99	27.7	186	3316	57.3	57.9	66.1
		Tail.	42.7	3.17	39.9	1704	5020	100.0	50.2	100.0
			100.0		50.2	5020				

TABLE 26

Results of Desliming Blended Head Sample with a Hydrocyclone

Product	Weight, %	S.G	$BaSO_4$ %	Barite Dist., %
Hydrocyclone ~~Water~~flow	69.9	3.50	59.1	75.9
Hydrocyclone Overflow	30.1	3.23	43.7	24.1
Reconstituted Feed	100.0	3.41	54.5	100.0

Hydrocyclone diameter, 4 in.
Feed solids concentration, 14.3% by weight

10.1 Discussion of Shaking Tabling Tests

As is apparent from Tables 21-25, the shaking table can produce high grade products from the Pine Brook barite ore, especially when the ore is ground finer than 0.5 mm. The difficulty arises from the relatively low recoveries obtained.

Figures 14, 15 and 16 show the variation of recovery with concentrate weight percentage for the ten shaking tabling tests. When one compares the actual recoveries with their respective ideal recovery curves (straight lines), clearly, at low concentrate weight percentages the recoveries are very close to the ideal values. However, when the concentrate weight percentages exceed 25%, the deviation of recovery from the ideal becomes rapid. Only Test no. 7, which was carried out on a feed previously deslimed by a hydrocyclone, gives substantial recoveries for higher concentrate weight percentages.

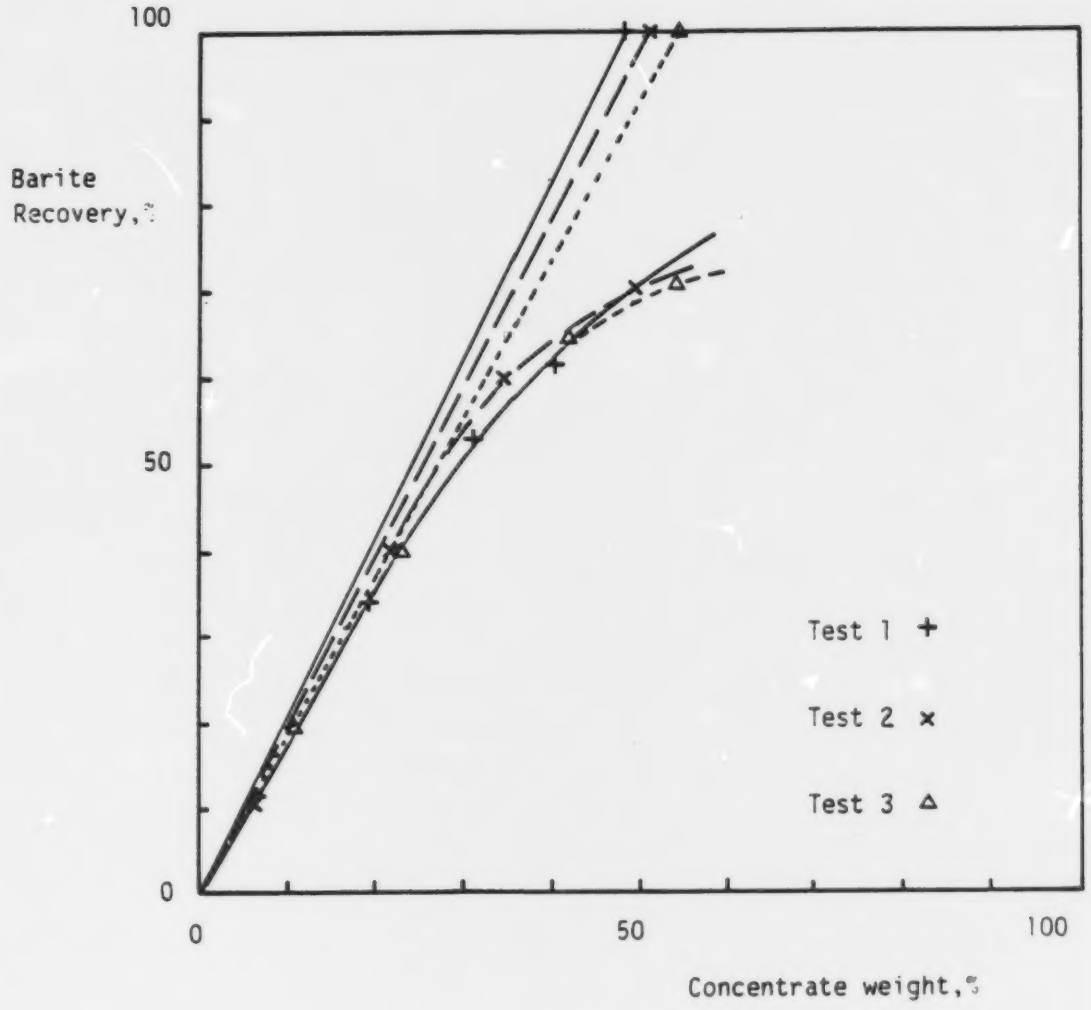


Figure 14. Barite Recovery Against Concentrate Weight Percent from Tabling Tests 1 to 3

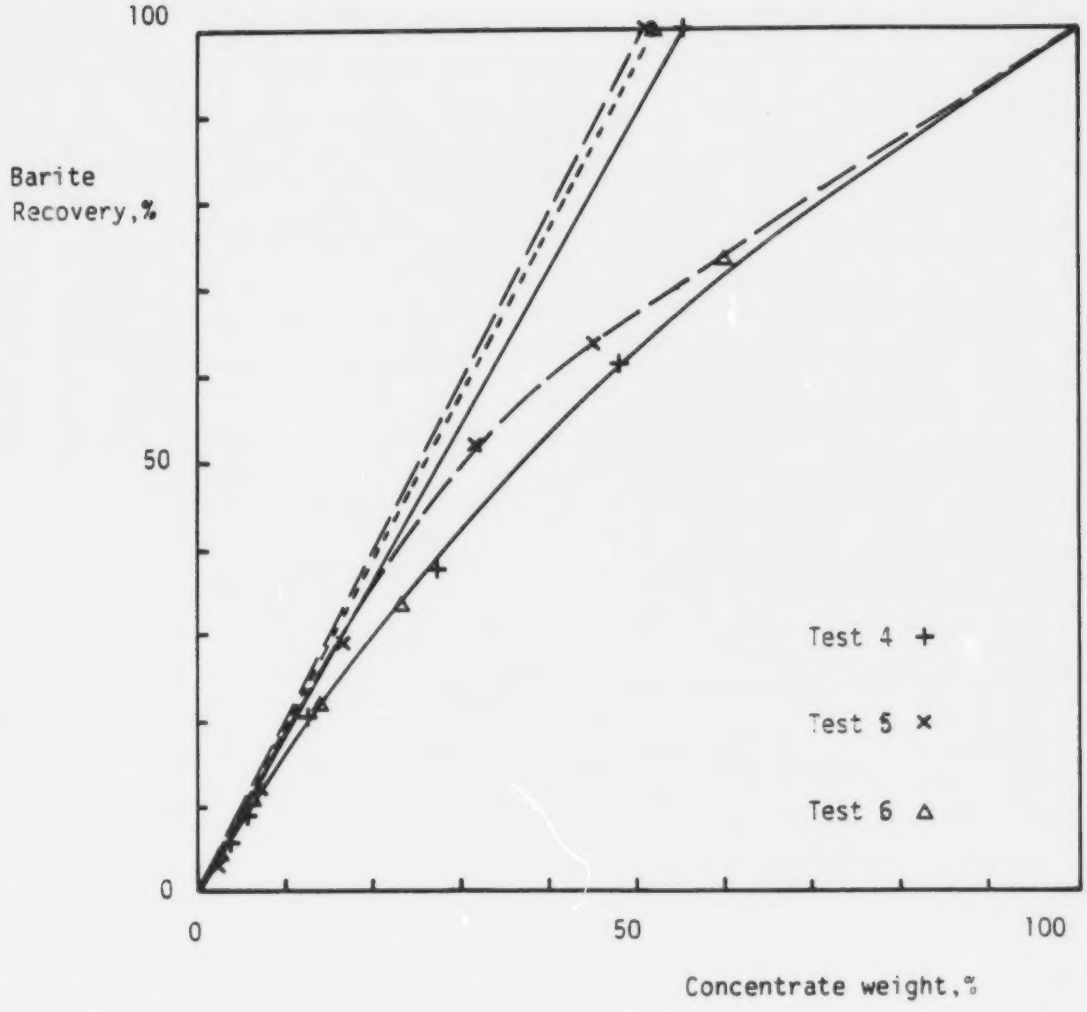


Figure 15. Barite Recovery Against Concentrate Weight Percent from Tabling Tests 4 to 6

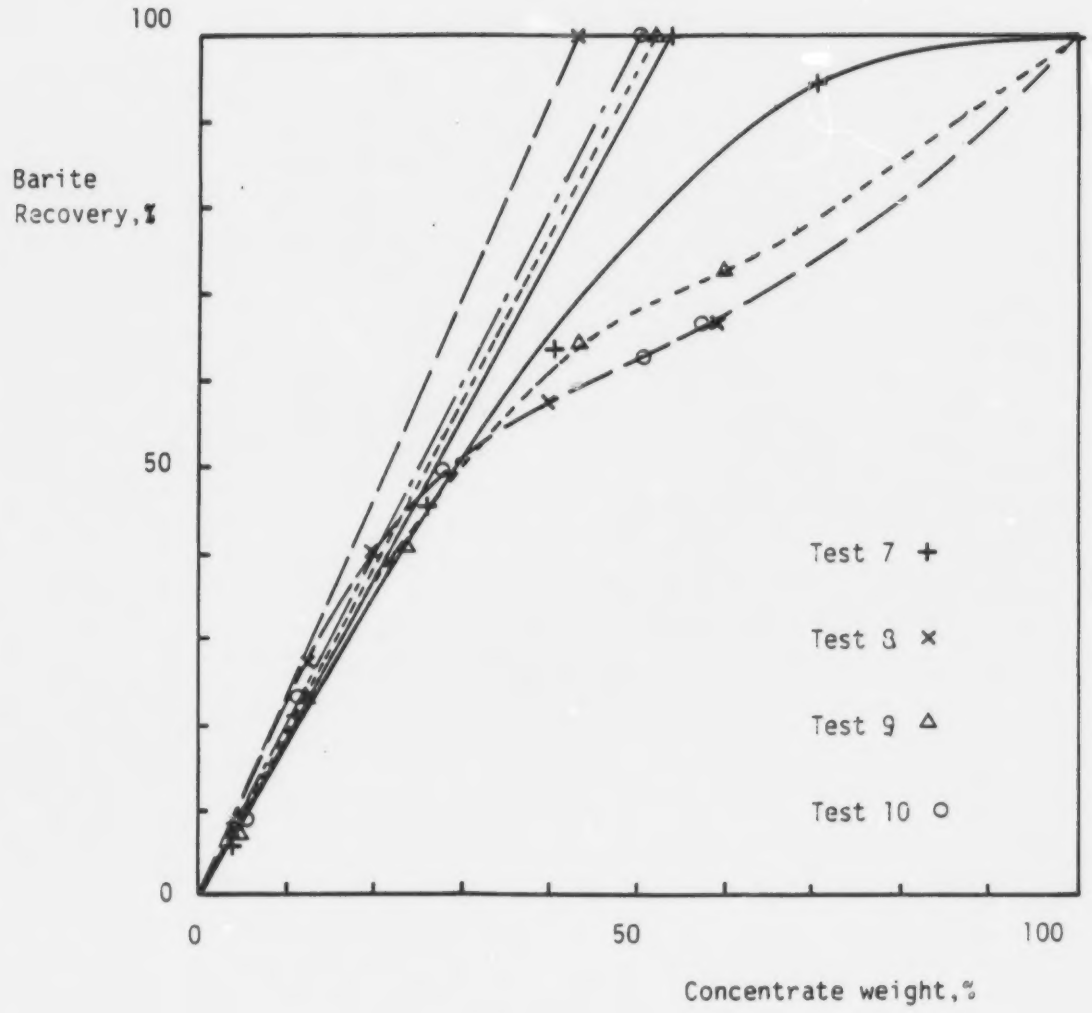


Figure 16. Barite Recovery Against Concentrate Weight Percent from Tabling Tests 7 to 10

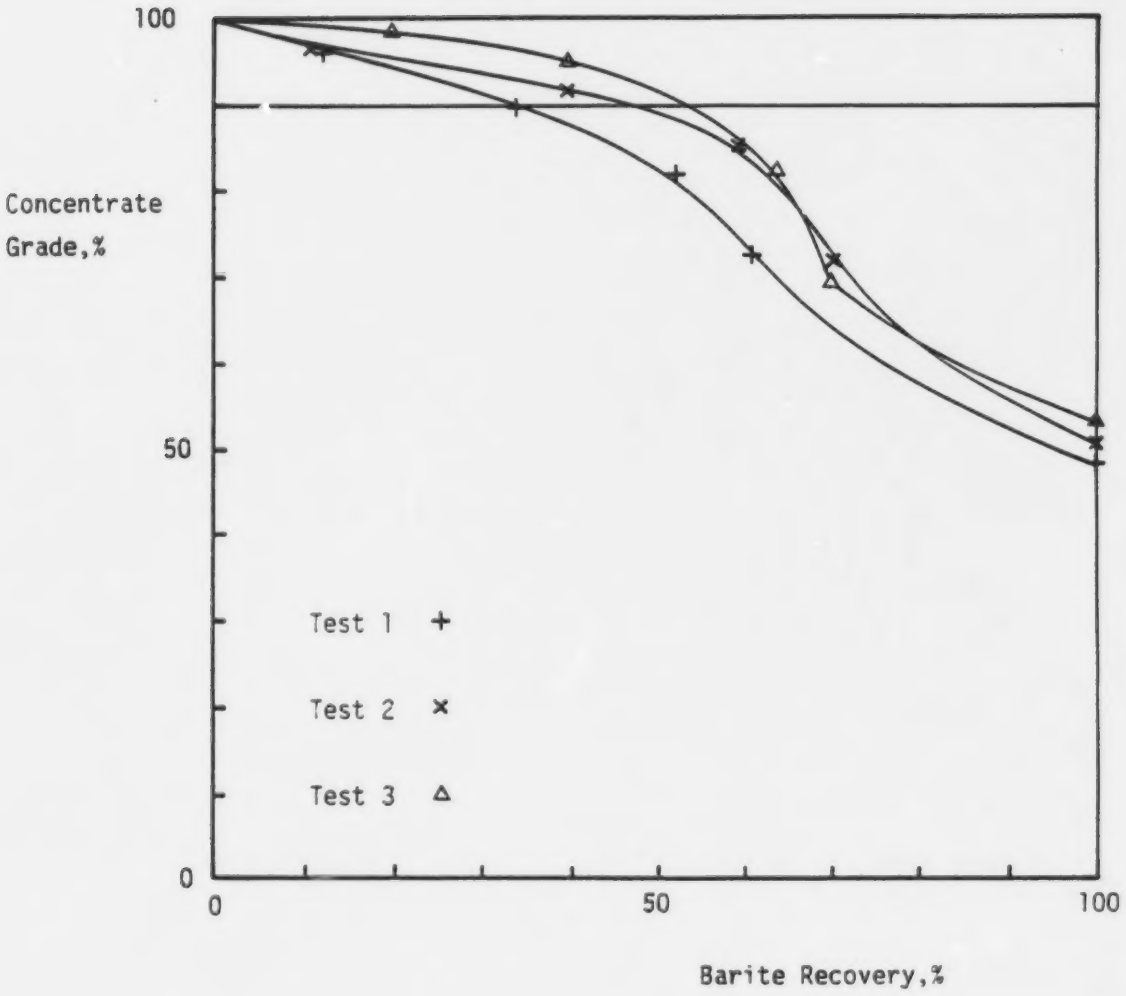


Figure 17. Concentrate Grade Against Barite Recovery from Tabling Tests 1 to 3

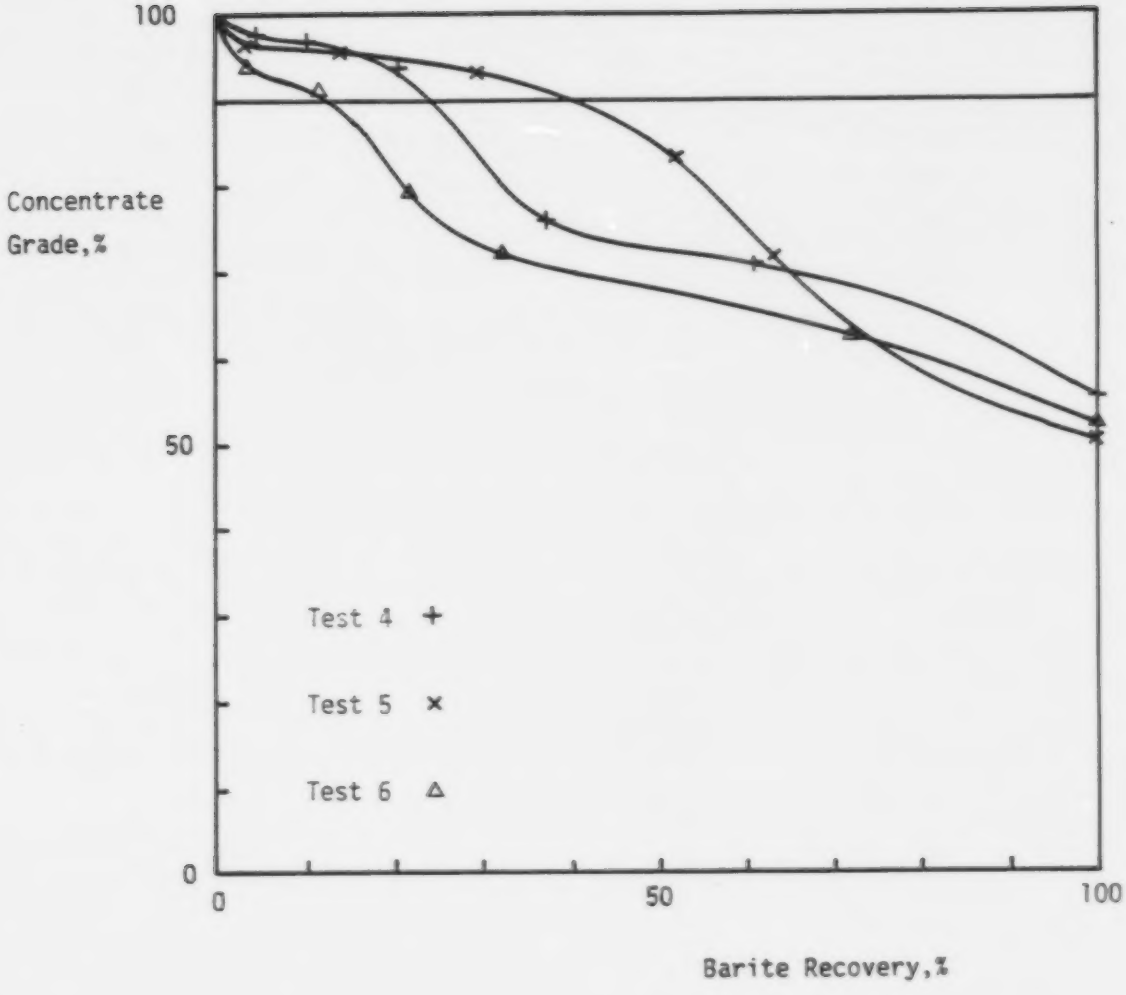


Figure 18. Concentrate Grade Against Barite Recovery from Tabling Tests 4 to 6

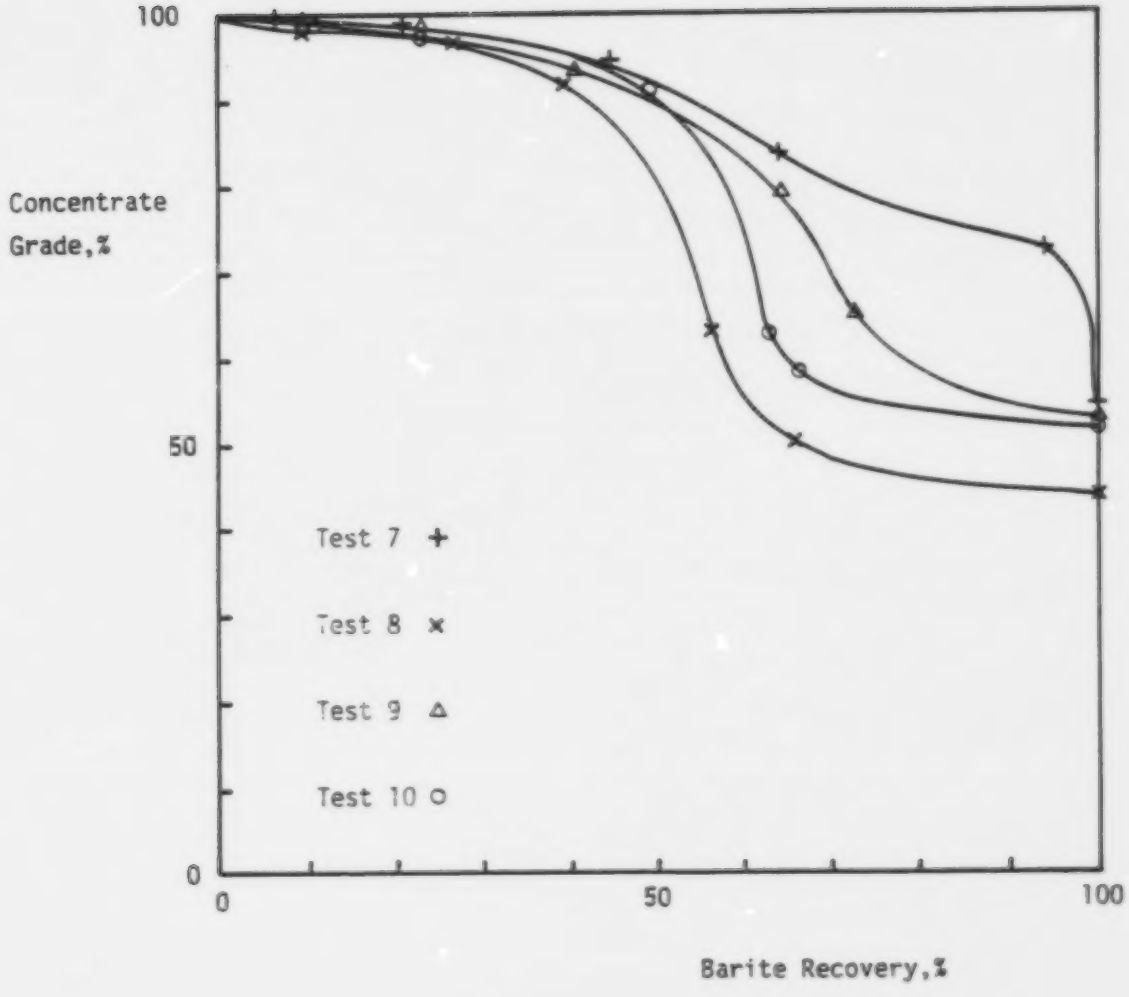


Figure 19. Concentrate Grade Against Barite Recovery from Tabling Tests 7 to 10

In Figures 17, 18 and 19 which give the concentrate grade variation with barite recovery for the ten shaking tabling tests, Tests nos. 1 and 2 on finer than 1 mm feed give low barite recoveries (32 and 45% respectively) at the approximately 90% barite grade equivalent to 4.2 S.G. required. Test no. 3 used a finer than 0.5 mm feed and produced 52% barite recovery at mud-grade. In Test no. 4 Middling 3 was recirculated by a small centrifugal pump to the feed box. This test gave only 25% barite recovery but the test was run at too high a feed rate which overloaded the deck. Test no. 5 was also run at a high feed rate of 2.2 kg/min. Here the Middlings 3 and 4 were collected and dried and retreated in Test no. 6. This simulated a roughing operation followed by a scavenging of the rougher middlings. The rougher operation, Test no. 5, had a barite recovery around 36%, while the scavenging produced approximately 13%. Since the barite distribution in Middlings 3 and 4 amounted to 33.4% the scavenging recovered a further 4.3% of barite, giving a total barite recovery of just over 40%. If both rougher and scavenger operations had been run with lower feed rates, the barite recoveries should have been higher.

When the shaking table was fed with deslimed feed, Test no. 7, it gave about 53% mud-grade barite recovery, but 24.1% of the barite was already lost in the cyclone overflow.

Test no. 8 refers to treatment of the ground tailings from jig Tests nos. 20, 21, 31, 32, 33 and 34. On the basis of jig Test no. 20, the jig recovered 57.7% of the barite in the concentrate at mud-grade and left 42.3% of the barite in the tailing. Since the shaking table recovered 40% of the barite from the tailing (Figure 19, Test no. 8) the shaking table recovery on feed basis amounted to 16.9% and the combined recovery by jig and table was 74.5%.

Test no. 9 was run on a blended head sample ground to finer than 0.5 mm. The main difference in operating variables for Test no. 9 was

the 3/4 in. stroke length, which produced greater transporting action of solids. This test recovered approximately 48% of the barite at mud-grade, a recovery slightly less than the best obtained in Test no. 3 under similar conditions but with 1/2 in stroke. It appears, therefore, that stroke length has little effect on barite recovery.

Test no. 10 was conducted with the sands deck which has deeper angled riffles. 3/4. in stroke and 5/8 in./ft transversal slope were used with finer than 0.5 mm feed. The distribution of minerals on the operating deck was markedly different with the sands deck. While the riffled portion of the fines deck was fairly uniformly loaded, the sands deck had very little mineral between riffles close to the feed end. The mineral bands were also more sharply defined than on the fines deck, which suggests that the separation on the sands deck was more selective. Inspection of barite recovery against concentrate weight of Test no. 4 (Figure 16), confirms very good recoveries up to 25% concentrate weight, followed by a sharp decline. As a result the barite recovery at mud-grade amounted only to 51% as seen in Figure 19.

The ten tests carried out on a shaking table, under varying operating conditions, showed that shaking tabling was able to produced high grade concentrates from the Pine Brook barite ore when it was ground to finer than 0.5 mm. However, barite recoveries were lower than normally expected at the degree of liberation occurring at this fine size. Barite recovery could be increased by using a roughing operation whose middlings would be retreated by scavenging tabling. However, the solids feed rate to a deck should be kept below 1 tonne/ hour, otherwise barite recoveries are likely to suffer.

It has been demonstrated that shaking tabling can recover substantial amounts of barite values from ground jig tailings, so that the combined recoveries of jig and shaking table could approach 73%. This

scheme appears to be more attractive than the use of shaking tables alone.

11. CONCLUSIONS FROM PILOT PLANT WORK

In Phase III, pilot plant work was carried out on the blended head sample of Pine Brook barite ore on Tri-Flo separator, Denver Mineral jig, Humphrey's and Reichert spiral concentrators and a Wilfley Laboratory shaking table. The capabilities of each concentration method are summarized below.

11.1 Tri-Flo Separation

Tri-Flo separation, when operated with 3.5 to 30 mesh barate ore feed, gave 75% barite recovery at 4.2 specific gravity of concentrate, under the best conditions. In this operation the 30 mesh to 0 fraction was not concentrated. The barite recovery for the whole 3.5 mesh to 0 feed amounted to about 55%. Therefore, if a dense medium separation process was to be considered for the Pine Brook barite, an alternative treatment would be needed for the 30 mesh to 0 fines.

11.2 Jigging

Jigging produced good results on the 3.5 mesh to 0 Pine Brook barite feed, giving up to 60% barite recovery at mud-grade. The most important operating variables in jigging were the depth of ragging bed and water flow rate. Deep beds or high flow rates tended to reduce barite recovery. Specific feed rates with high recoveries ranged from 8-14t/h/m^2 and specific water consumptions were in the range of 70-90 $m^3/h/m^2$.

11.3 Spiral Concentration

Neither the Humphreys nor the Reichert spiral concentrators achieved sufficiently high concentrate grade for use as mud-grade barite. Test no. 4 produced 86.8% barite at 23.7% barite recovery. So it appears that spiral concentration is not a suitable method for use with the Pine Brook barite ore.

11.4 Shaking Tabling

Shaking tabling tests confirmed that when operating on a minus 0.5 mm blended feed, mud grade barite could be obtained at up to 53% barite recovery.

Shaking tabling also worked well on the jig tailing ground to finer than 0.5 mm, recovering up to 40% barite values from the tailing and increasing the combined barite recovery to about 73%.

The solids feed rate for a full size deck should be around 1 t/h and total water requirements would range from 10-14 m^3/h.

Table 27 summarizes the recovery figures obtained for the various concentrators.

TABLE 27

Barite Recoveries at 4.2 Specific Gravity (Mud-Grade)

Concentrator	3.5 - 30 mesh	3.5 mesh - 0	0.5 mm - 0
Tri-Flo concentrator	75	55	-
Mineral jig	-	60	-
Humphrey's spiral	-	-	Below grade
Shaking table	-	-	53
Jig and table	-	57.7	16.9

12. SPECIFICATIONS FOR MUD GRADE BARITE

Mud grade barite must conform to the specifications laid down by certain professional bodies including the American Petroleum Institute. A primary requirement is that the specific gravity of the barite is at least 4.2 This condition has been satisfied by concentrating to a grade whose specific gravity is over 4.2

Another requirement is that the soluble alkaline earth metals, as calcium, do not exceed 250 ppm. To evaluate the earth metal content a combined sample of concentrates from jig tests nos. 20, 21, 31, 32, 33, 34, was analysed for soluble alkaline earth metals and was found to contain 40 ppm. Similarly, the shaking table concentrate and middlings 1 and 2 from tabling test no. 8 were combined and analysed and contained 42 ppm. Other elemental analyses were also conducted as given in Tables 28 and 29.

TABLE 28: Results of Chemical Analysis of Jig Concentrator

$BaSO_4$	$SrSO_4$	SiO_2	Al_2O_3	Fe_2O_3	CaO	CO_2	C
89.10	2.03	2.70	0.82	0.40	4.32	2.60	0.33

ppm

Cu	Pb	Zn	Cd	Soluble Alkaline Earth Metals as Calcium
330	796	1100	16	40

TABLE 29: Results of Chemical Analysis of Shaking Table Concentrate

$BaSO_4$	$SrSO_4$	SiO_2	Al_2O_3	Fe_2O_3	CaO	CO_2	C
87.7	1.88	3.98	0.99	0.83	3.08	2.23	0.09

ppm

Cu	Pb	Zn	Cd	Soluble Alkaline Earth Metals as Calcium
436	1240	1050	15	42

The requirement regarding size analysis is that in wet sieving the weight percentage coarser than 200 mesh must not be greater than 3% and the coarser than 325 mesh not greater than 5%. This condition will be satisfied by dry grinding to the required fineness.

PHASE IV

13. CONCEPTUAL DESIGN OF A BARITE TREATMENT PLANT

The contract stipulated that Phase IV should consist of a conceptual design for a plant to treat 200 tonnes daily of Pine Brook barite ore to produce mud-grade barite.

The design is based on the findings of test results obtained from the work carried out in Phases II and III. The choice of Treatment methods results from the implications of test results, some consideration of capital and operating costs of the relevant alternatives and on some common sense assumptions with regard to the operation of the proposed plant. The proposed plant should operate at the predicted performance level on barite ore of the same characteristics as that of the blended head sample used for the test work. However, since ore characteristics are very specific, if the ore feed to the plant should deviate significantly, the given plant specifications should not be used. The blended head sample tested represented an ore of relatively difficult separation characteristics. With more selective mining, a higher grade and more easily liberated ore could be produced which would give considerably higher barite recoveries with similar treatment.

13.1 Choice of Treatment Method

The contract specified that consideration be given to the use of gravity separation for upgrading the Pine Brook barite ore and, therefore, the work was restricted to those gravity separation methods which were likely to be appropriate in this case.

Dynamic dense medium separation using a Tri-Flo separator was tested and gave acceptable results on the 3 1/2 mesh to 30 mesh size range, returning 75% recovery at 4.2 concentrate specific gravity. However, dense medium separation is quite expensive, both in capital and operating costs, and the process would be operating at a high

specific gravity of separation, near its practical limit. Additionally, Tri-Flo separation would not be capable of treating the finer than 30 mesh portion and, therefore, overall recovery for the 3 1/2 mesh to 0 feed would only be about 55%. Thus, Tri-Flo separation was not considered to be a viable treatment method in this instance.

Jigging is capable of treating all of the 3 1/2 mesh to 0 barite ore and test results indicated that mud-grade barite concentrate could be produced with up to 60% barite recovery. Jigging is a high throughput process which could operate at around 12 t/h for every square metre of jig screen area and so it would have relatively low capital and operating costs. Thus, jigging has been selected as one of the options.

Spiral concentration was unable to produce the required grade and therefore has not been considered further.

Shaking tabling has shown that it is capable of producing high grade barite concentrate, but operating alone, even on feed ground finer than 0.5 mm, it was unable to return more than 53% barite recovery. However, it has been shown to be efficient for the recovery of barite from the ground jig tailings, giving recoveries up to 40%.

Consequently, the conceptual design of the plant for treating Pine Brook barite ore will be based on jigging of the feed followed by shaking tabling of the ground jig tailing.

13.2 Description of Proposed Flow Diagram

The descriptive flow diagram of the plant is given in Figure 20. The run of mine Pine Brook barite ore is unloaded from trucks or belt conveyor to a surge bin. The surge bin discharges onto a grizzly. The grizzly oversize product is crushed in a jaw crusher and together with the grizzly fines is transported by belt conveyor to a 3 1/2 mesh vibratory screen. The screen oversize is crushed in a short

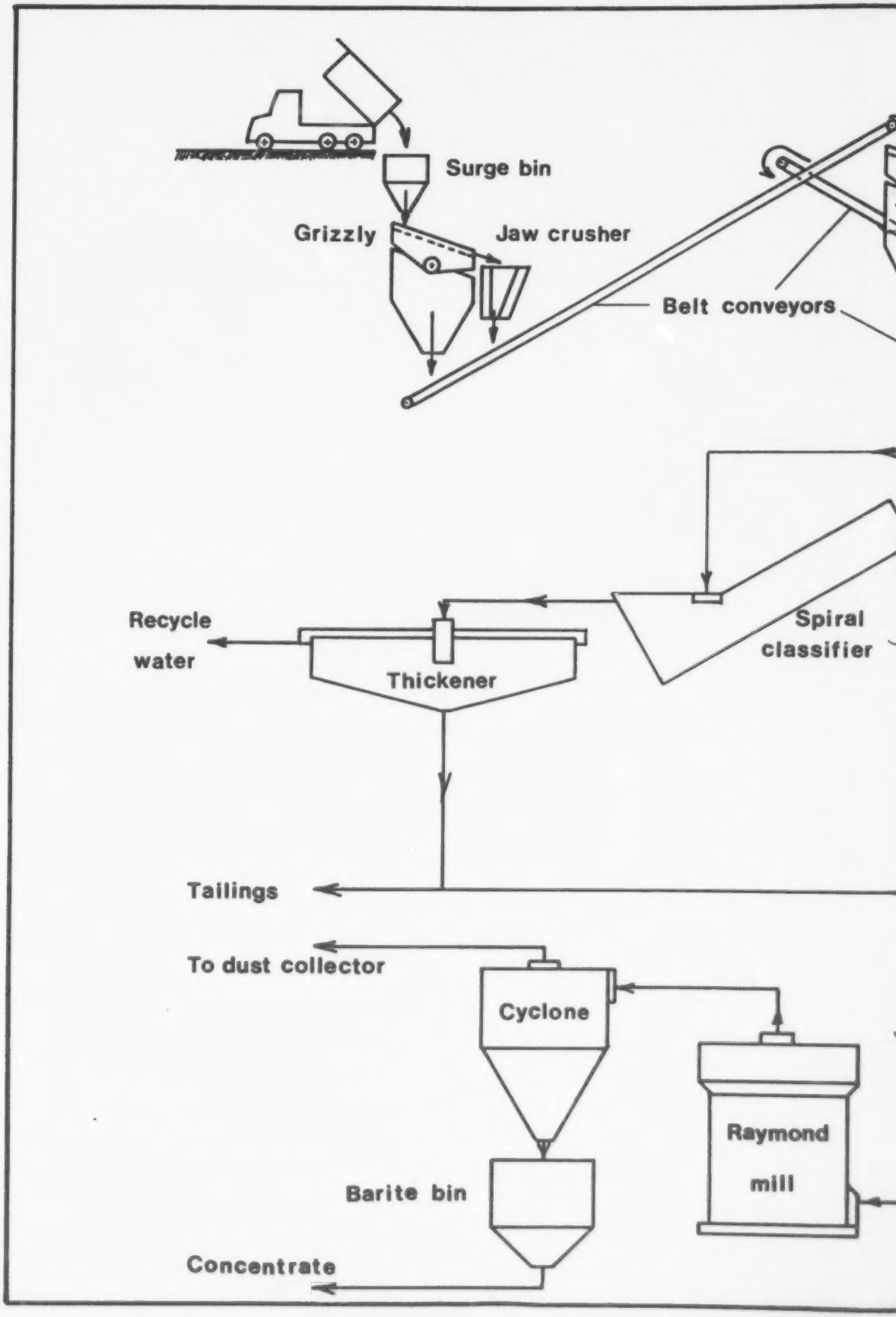
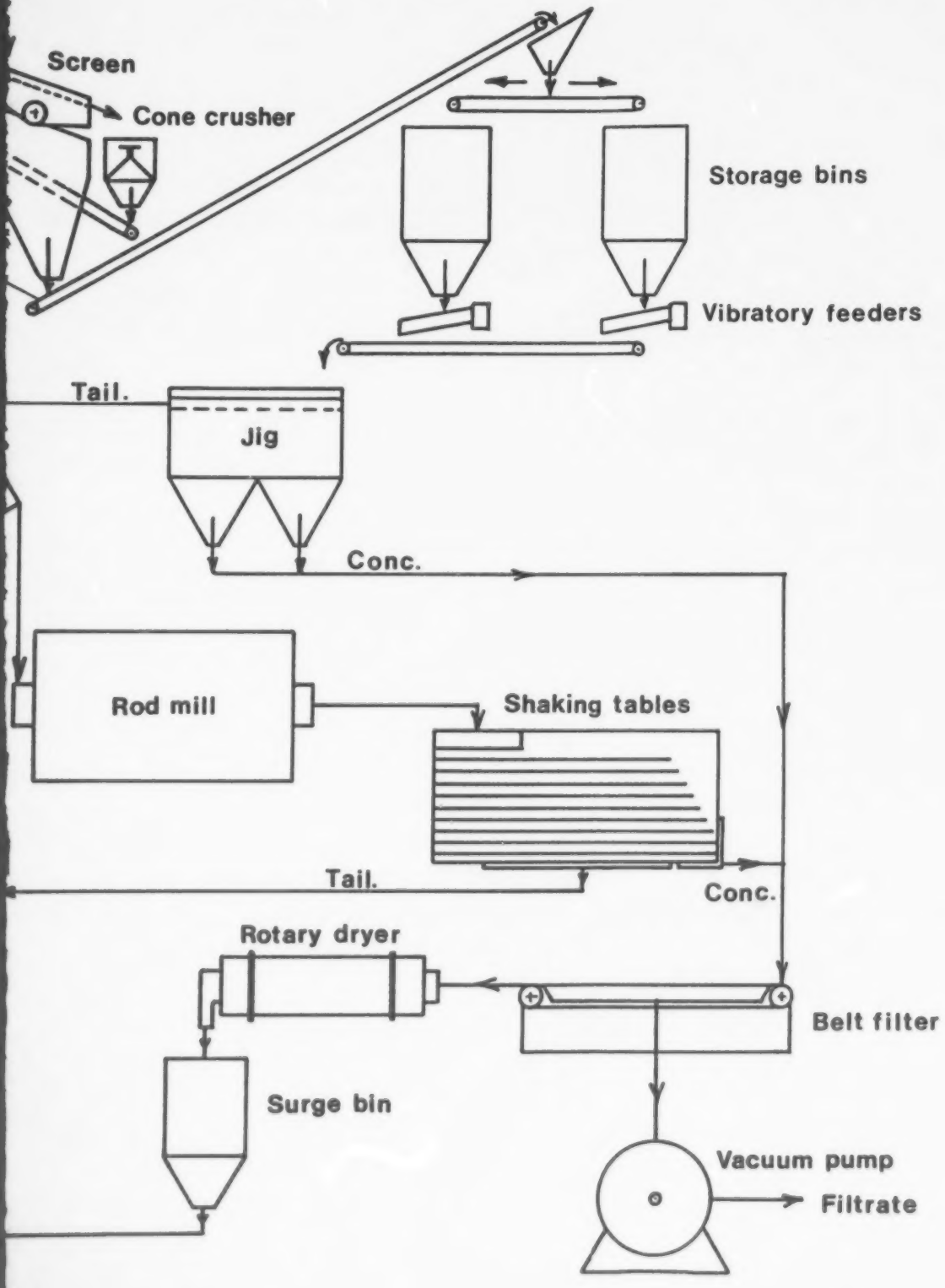

Surge bin
Grizzly
Jaw crusher
Belt conveyors
Recycle
water
Thickener
Spiral
classifier
Tailings
To dust collector
Cyclone
Raymond
mill
Barite bin
Concentrate

Figure 2



). Descriptive flow diagram.

head cone crusher and the crushed product is recirculated to the screen. The screen undersize forms the fine ore for treatment, which is transported by belt conveyor to two fine ore storage bins. The storage bins will allow for blending of the fine ore. The fine ore is withdrawn from the two bins by vibratory feeders and loaded on a conveyor belt for transport to the mineral jigs. Extracting ore from both bins simultaneously will improve the homogeneity of the fine ore feed.

The concentration process commences in a two compartment mineral jig. Here the jig operates as a rougher-concentrator. The jig concentrate is a final concentrate which will be filtered, dried and ground. The jig tailing is further treated to recover more barite by grinding and shaking tabling, but prior to grinding, the jig tailing has to be dewatered for which a spiral classifier is used. The spiral classifier also performs a desliming operation in which the fine low grade clayey material is rejected in the spiral classifier overflow. The overflow reports to a thickener where flocculant is added and the solids sediment out to form the thickener underflow sludge. This underflow is a slime tailing. The thickener overflow is recyclable water. The spiral classifier sands product reports to a rod mill for grinding to finer than 0.5 mm. The rod mill product is treated on shaking tables to make a barite concentrate and a final tailing. The shaking tables operate as scavenger concentrators. The sand tailing from the shaking tables joins the slime tailings from the thickener for transportation to the tailings disposal area.

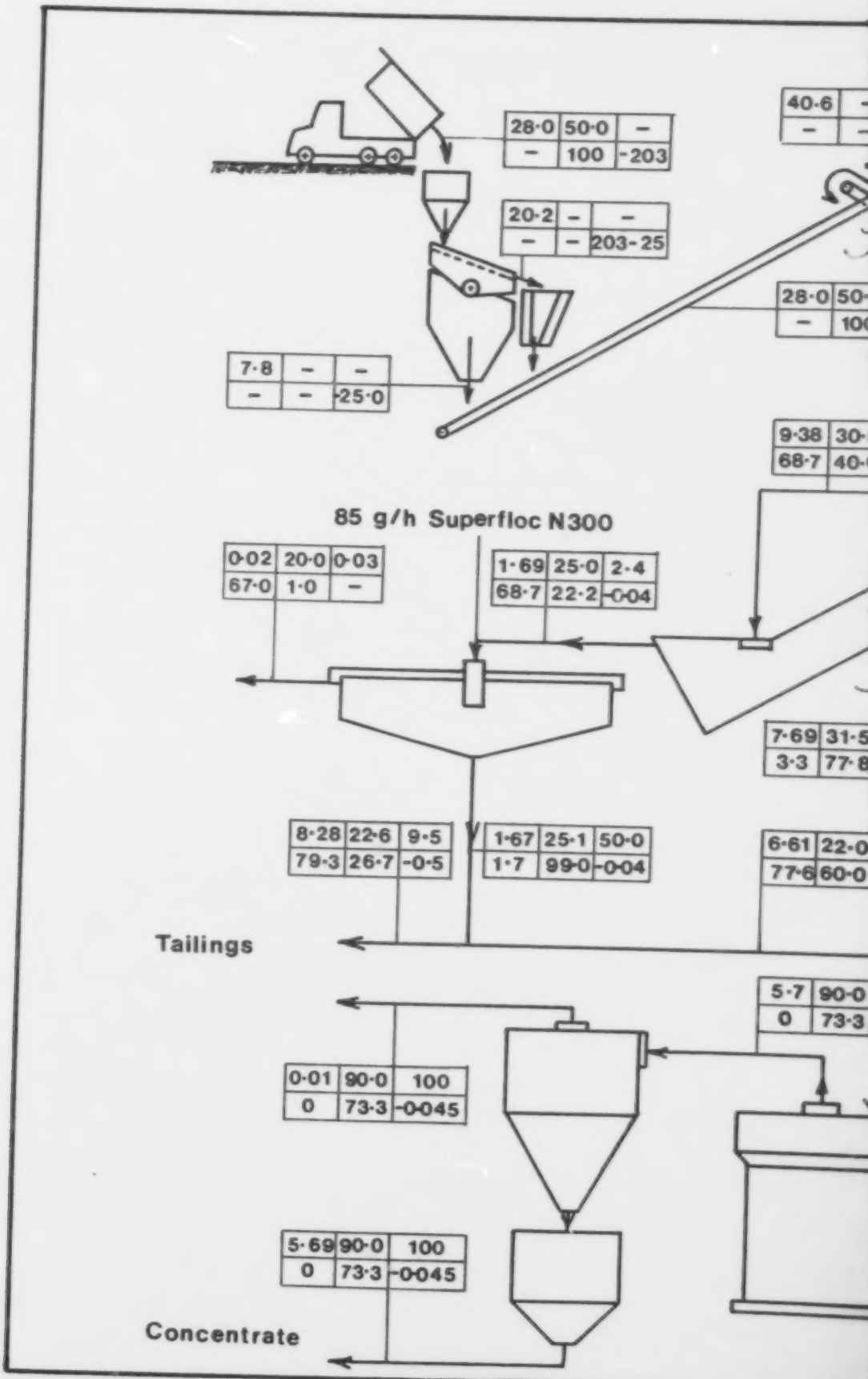
The shaking table concentrate is dewatered and filtered on a horizontal belt filter and dried in a rotary dryer fitted with a dust collector. The dried product is stored in a bin prior to feeding to a Raymond mill, which grinds the dried concentrate to 95% finer than 45 µm. The ground product from the Raymond mill is recovered as a dry cyclone underflow and is stored in a concentrate storage bin. The cyclone overflow goes to a dust collector.

The flow diagram of the proposed plant was planned to be simple and functional, since a plant with a simple flow circuit is likely to have lower capital costs and be easy to control. Since no middling recirculation is included in the concentration section, surges of middlings build up in the circuit are eliminated.

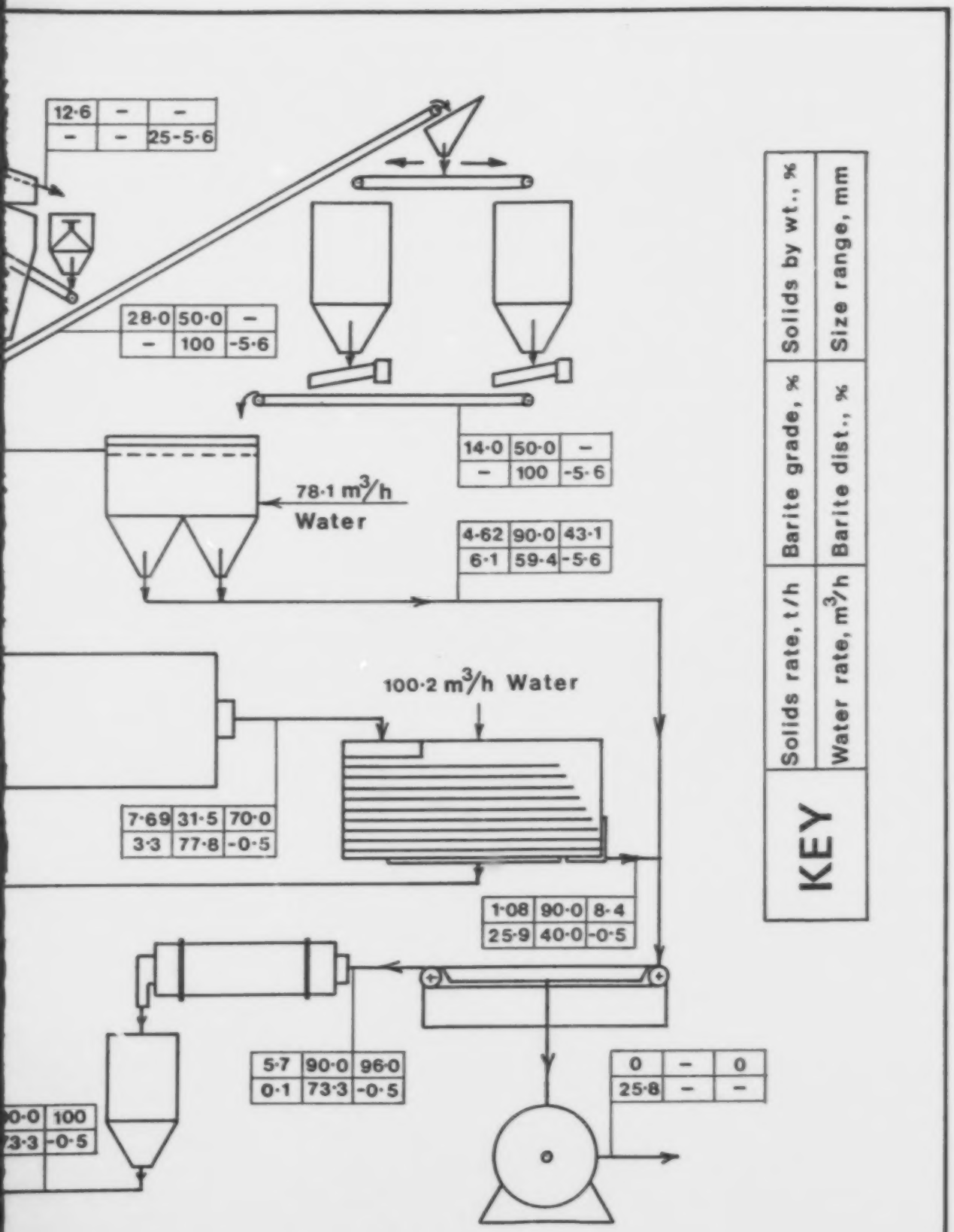
13.3 Flow Circuit Calculations and Equipment Sizing

The mine produces 200 tonnes of run of mine ore daily. It is assumed that the crushing plant operates over an eight hour day and the concentration section operates two eight hour shifts daily. If fifteen minutes start up time is allowed for the crushing and thirty minutes for the concentration section, then their feed rates would be 25.8 t/h and 12.9 t/h respectively. With an allowance of 8.5% excess capacity, the sections are designed for feed rates of 28 t/h and 14 t/h. The run of mine ore is assumed to be finer than 203 mm (8 in.) with a feed grade of 50% $BaSO_4$. The calculated circuit flow values are shown in Figure 21 and the equipment specifications in Figure 22.

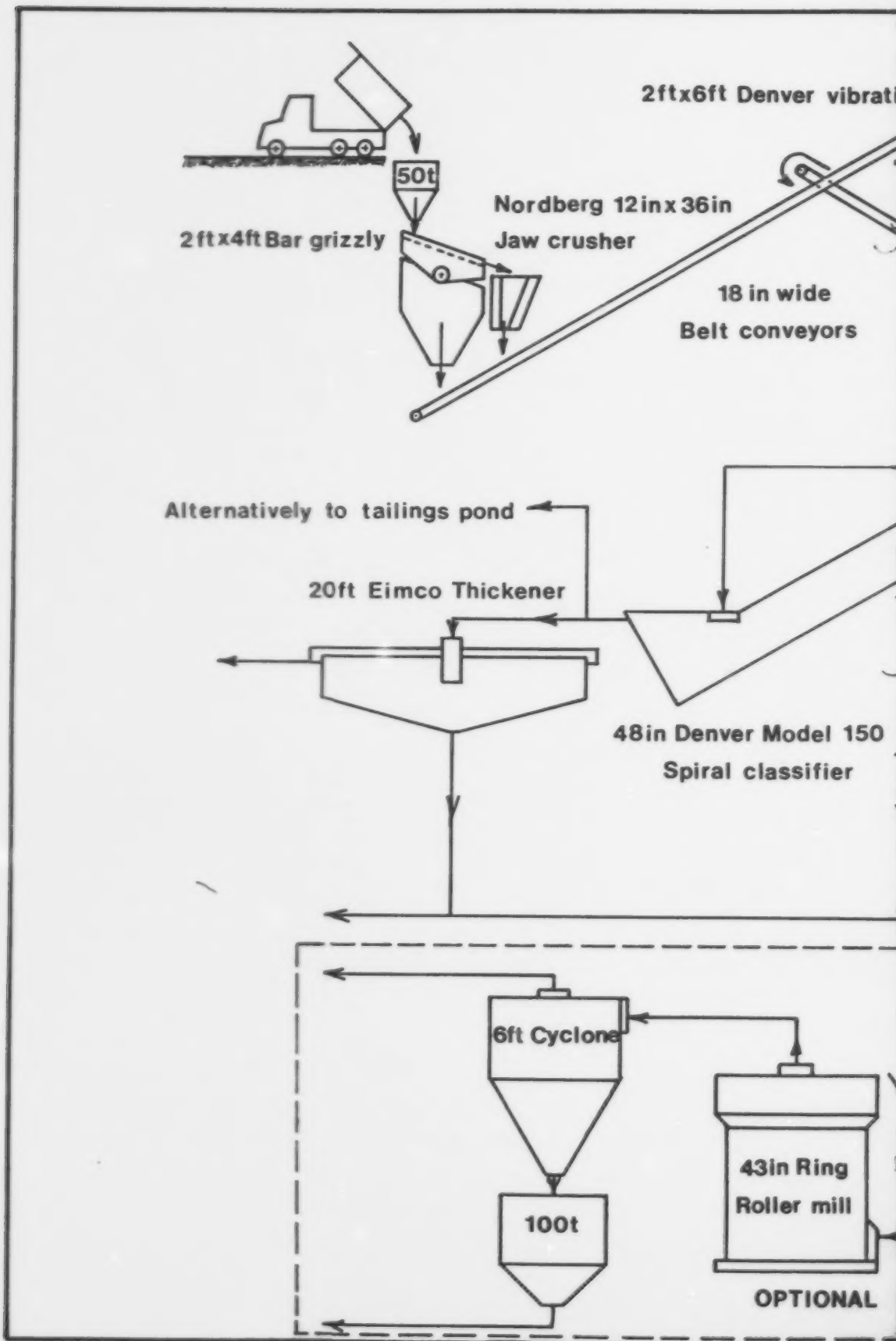
Run of mine ore is delivered into a 50 t surge bin, which holds 1.75 h feed tonnage. The surge bin feeds onto a 1 in vibrating bar grizzly 2 x 4 ft. On the basis that 28% of the ore passes through the grizzly, 7.8 t/h is undersize and 20.2 t/h is oversize which is crushed in a jaw crusher. A Nordberg 12 x 36 in jaw crusher is chosen, operated at 1.5 in closed side setting, with a capacity of 36.2 t/h, Ref. 1, 8-2. There is excess capacity here, but due to the maximum particle size of feed this size of crusher is required. The undersize from the grizzly and the crushed product are transported by an 18 in wide belt conveyor to a vibrating screen with 5.6 mm (3.5 mesh) apertures. The screen undersize is a finished fine ore product while the oversize is crushed in a short head cone crusher in closed circuit with the screen. From Ref. 1, 8-3, the jaw crusher has 20% finer than 5.6 mm material in its product. Ref. 1, 3-7, gives that a


28·0 50·0 –
– 100 -203
20·2 – –
– – 203-25
7·8 – –
– – -25·0
40·6
28·0 50
100
9·38 30
68·7 40
85 g/h Superfloc N300
0·02 20·0 0·03
67·0 1·0 –
1·69 25·0 2·4
68·7 22·2 -0·04
7·69 31·5
3·3 77·8
8·28 22·6 9·5
79·3 26·7 -0·5
1·67 25·1 50·0
1·7 99·0 -0·04
6·61 22·0
77·6 60·0
Tailings
5·7 90·0
0 73·3
0·01 90·0 100
0 73·3 -0·045
5·69 90·0 100
0 73·3 -0·045
Concentrate

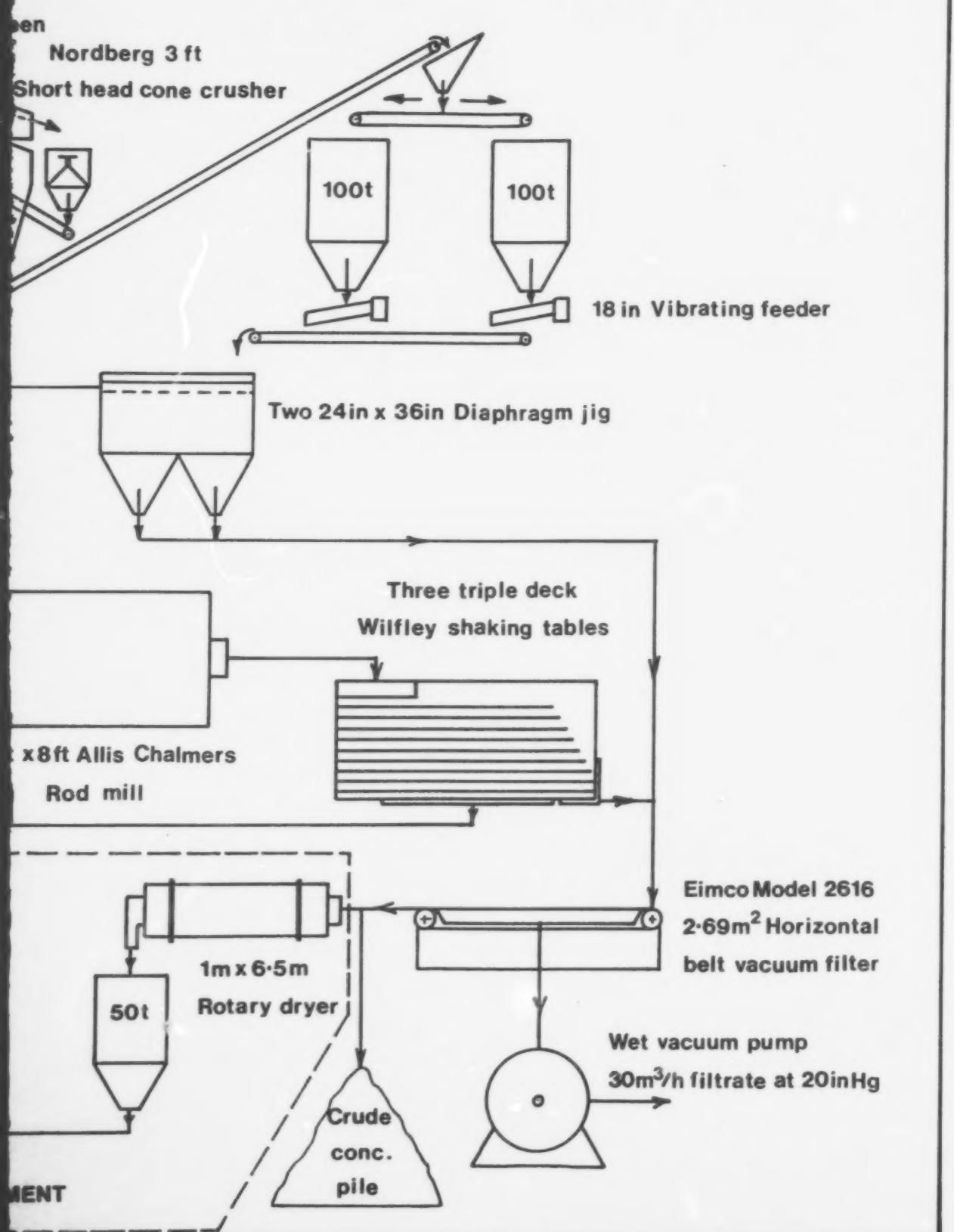
Fig



Circuit flow values.


2ftx6ft Denver vibrati
50t
Nordberg 12inx36in
Jaw crusher
2ftx4ft Bar grizzly
18 in wide
Belt conveyors
Alternatively to tailings pond
20ft Eimco Thickener
48in Denver Model 150
Spiral classifier
6ft Cyclone
43in Ring
Roller mill
100t
OPTIONAL

Figure



Equipment specifications

short head cone crusher operating at 1 1/2 m closed side setting produces 58% finer than 5.6 mm. A screen efficiency of 95% is assumed and, therefore, the tonnage of minus 5.6 mm fines that is required for the screen is 28/0.95 = 29.2 t/h. But the feed contains 0.2 x 28 = 5.6 t/h minus 5.6 mm material, so the crusher must produce 23.6 t/h. From the fines balance of 28 x 0.58 x (1 + CL) = 23.6, the circulating load is CL = 0.45 or 12.6 t/h. Consulting Ref. 1, 3-10, the suitable machine is a Nordberg 3 ft diameter short head cone crusher, with coarse cavity set at 1/4 in closed side setting. This will have adequate feed opening to accommodate the jaw crusher product. The capacity of this crusher for net finished product is 31.7 t/h and for total passing through is 68.0 t/h. However, the requirement is only 12.6 t/h. This size is necessary to allow for the maximum size of the feed.

The size of the screen has been determined for a 40.6 t/h (44.8 sht/h) and 5.6 mm (0.22 in.) screen aperture by a computer program developed by the author. The screen size determination is based on the method given in Ref. 3, 3E-16 to 3E-19. The computer print out is given in Appendix B. Here a relief deck is assumed for the screen. The screen area required is 10 ft^2. From Ref. 2, page 21, the nearest screen is a 2 ft x 6 ft Denver Vibrating Screen.

The screen product is transported to two fine ore bins by an 18 in conveyor. This has far too large a capacity but is the smallest suited for industrial use, Ref. 1, 1-1. Two bins of 100 t, or one of 200 t, capacity provide for one day's supply of fine ore, feeding onto the 18 in. wide vibrating feeder. This is the smallest available, Ref. 1, 10-1. A belt conveyor transports the fine ore from the feeder to a diaphragm type mineral jig, Ref. 2, page 25. The jig is fed at 14 t/h. From our tests, the specific jig capacity found was about 13 t/h/m^2. Therefore, screen area of jig required is 1.08 m^2. A 24 x 36 in Denver Duplex jig has a screen area of 0.56 m^2. Therefore, two of these jigs would suffice. In tests on the blended barite ore, 33% of the feed reported to the concentrate, equivalent

to 4.62 t/h and 9.38 t/h to the tailing. Since in the tests the jig used 69.7 $m^3/h/m^2$ water, the total water requirements of the two jigs are 78.1 m^3/h. Assuming that the jig concentrate contains 43.1% solids and the total amount of water in the concentrate is 6.1 m^3/h the tailing contains 72.0 m^3/h.

A spiral classifier was chosen as it will not only dewater the tailing but will also reject some of the low density fines. If 18% of the feed solids report to the overflow, then 1.69 t/h slimes are rejected and 7.69 t/h sands are recovered. The sands capacity of a 48 in. spiral is 320 sht/24h, (Ref. 4, 8-14) and its overflow capacity for 325 mesh (45 μm) is 45 sht/24h, (Ref. 4, 8-18). Since the sands capacity required is 204 sht/24h and the overflow capacity required is 44.8 sht/24 h, the 48 in spiral should be adequate. The chosen spiral classifier is a Denver, Model 150, 48 in. diameter, (Ref. 5, page 18). If the sands product solids concentration from the spiral classifier is 70%, then 3.3 m^3/h water will be in the sands reporting to the rod mill, while the overflow will contain 68.7 m^3/h at 2.4% solids which reports to a thickener.

The rod mill designed to grind 7.69 t/h solids from an 80% passing feed size of 4.2 mm to an 80% passing product size of 0.36 mm. The Bond work index obtained from grindability tests is approximately 11 kWh/t. A peripheral discharge mill at 40% mill loading is selected as it produces less fines. The complete printout of the rod mill sizing is given in Appendix C. The method used is described in Ref. 6, pages 393-438. The size of the rod mill is 1.52 m (5 ft) diameter by 2.44 m (8 ft) length, operating at 25.7 rpm, 71.2% critical speed. The mill power required is 45 kW. Replacement rod diameter is 65 mm and length is 2 m.

The shaking tables receive 7.69 t/h solids at 70% solids concentration from the rod mills. If this feed rate is distributed over three triple deck Wilfley shaking tables the feed rate per deck is 0.85

t/h. The water requirements scaled up from the test figures give 11.5 m^3/h for every deck or 103.5 m^3/h in total. Since 3.3 m^3/h comes from the ball mill, the additional water amounts to 100.2 m^3/h. If 14% of the feed solids are recovered in the concentrate at 90% barite grade, then this amounts to 40% barite recovery. There will be 6.61 t/h tailing at 22.0% grade and 60% distribution.

The thickener receives 1.69 t/h classifier overflow solids and 68.7 m^3/h water. The feed is flocculated with Cyanamid Superfloc N300 flocculant at a dosage of 0.05 kg/t. This amounts to 85g of flocculant per hour added in a 0.01% solution. The thickener design is based on batch sedimentation test results obtained with the hydrocyclone overflow, which is similar in character to the spiral classifier overflow. The calculation uses the Talmage and Fitch method, (Ref. 7 pages 343-348). A computer printout of the thickener design results is given in Appendix D. The thickener selected is a 6m (20 ft) diameter by 1.3 m (5 ft) high Eimco high capacity thickener with flocculation in the feed well. The underflow solids concentration is expected to be 50% by weight and the overflow water to contain 0.03% solids, or 0.3 g/L. If sufficient tailings pond area is available, flocculation and thickening may not be required.

The jig concentrate and shaking table concentrate together amount to 5.7 t/h with 32 m^3/h water. The solids concentration of the combined concentrates is 15.1%, too low to feed to a filter, and therefore the concentrate will be dewatered in a spiral classifier prior to filtration. An alternative choice would be to only filter the table concentrate which is a smaller quantity, but dewatering will also result in thorough mixing before filtration and therefore this scheme is preferred.

The spiral classifier received 5.7 t/h solids at 15.1% solids concentration. The solids concentration of the sand product is assumed to be 70%. A 48 in. diameter Denver Model 150 spiral classifier is adequate for this duty and has the advantage of using the same spares as

the other spiral classifier, dewatering the rod mill feed. The spiral classifier dewatering the feed to the horizontal belt filter is not included in the plant flow diagram. The horizontal belt filter feed is 5.7 t/h at 70% solids concentration. Since the feed is coarse and sediments out almost immediately on the horizontal belt filter, it is safer to size the filter to allow for the total amount of filtrate to pass through the whole cake thickness, rather than to assume that the cake builds up gradually requiring only half the filtration area.

The volume rate of water fed to the filter is 5.7 x 0.3/0.7 = 2.45 m^3/h. The filter cake volume per hour, assuming 35% cake voidage and 4.2 specific gravity of solids is 5.7/4.2/(1-0.35) = 2.09 m^3/h. The volume of water in cake per hour is 0.35 x 2.09 = 0.73 m^3/h; therefore the filtrate volume is 2.45 - 0.73 = 1.72 m^3/h.

The specific resistance of filter cake as determined in a batch filtration test is 9.2 x $10^{12} m^{-2}$. A cake thickness of 25 mm and filtration vacuum of 60.9 kPa (18 in Hg) are assumed. Since this is constant rate filtration at constant pressure, the filtration rate is proportional to filtration area and filtration pressure and inversely proportional to specific resistance of cake, filtrate viscosity and cake thickness. Therefore, the filtration area requires is 1.72 x 9.2 x 10^{-3} x 0.025/60.9 x 10^3/3600 = 1.8 m^2 (19.5 ft^2). The filtration area per hour is 2.09/0.025 = 83.6 m^2/h. Therefore, the filtration time is 1.8 x 3600/83.6 = 78 seconds.

An Eimco Model 2616 belt filter has a filtration area of 2.68 m^2 (29 ft^2), (Ref. 8). Assuming an effective belt width of 0.5 m and a working length of 5.4 m, then the first 1.8/0.5 = 3.6 m of the belt is used for filtration over a period of 78 seconds and the remaining 1.8 m of the belt for cake drying, with a drying time of 39 seconds. The belt speed is 60 x 3.6/78 = 2.77 m/min.

The filtered concentrate is a crude barite product and may be sold as such. However, if a mud-grade barite product is desired, the crude concentrate must be dried and ground to mud-grade specifications with the following equipment.

The rotary dryer receives 5.7t/h solids at 96% solids concentration. The 4% moisture content of the combined concentrates was determined in a laboratory test and amounts to 0.24 m^3/h water, which has to be evaporated by the dryer.

The heat required to raise the temperature of 5700 kg of solids from a feed temperature of 10C to a leaving temperature of 95C is 5700 x 0.23 x 85 = 111,500 kcal/h. The specific heat of barite was assumed to be 0.23 kcal/kg. The heat required to raise the temperature of water from 10C to 95C is 240 x 1 x 85 = 20,400 kcal/h. The heat required to evaporate the water present, whose heat of evaporation is 539 kcal/kg is 240 x 539 = 129,000 kcal/h. Therefore, the total heat requirement for drying is 261,260 kcal/h or 0.252 x 261,260 = 65,838 Btu/h. Assuming 50% thermal efficiency, the total heat input is 523,000 kcal/h or 132,000 Btu/h. Using a fuel oil of 10,000 kcal/kg thermal value, the rate of fuel consumption is 52.3 kg/h or 57 L/h.

The rotary dryer volume required, assuming direct feed fired heating at 3 lb water evaporation per hour for every cubic foot of the dryer volume, or 48.4 kg/m^3, is 240/48.4 = 5m^3, (Reference 3, page 9-37). This gives a 1 m diameter and 6.5 m long rotary dryer. The rotary dryer product discharges into a 50 t surge bin.

In the Raymond mill, 5.7 t/h finer than 0.5 mm dried barite concentrate is ground to finer than 45 µm. The 80% passing feed size is estimated as 350 µm and the 80% passing product size as 32 µm. The power required to grind the concentrate of 7 kWh/t work index (estimated) is 5.7 x 10 x 7 x ($1/32^{0.5} - 1/350^{0.5}$) = 49.2 kW. Allowing 10% for transmission losses, the power needed is 55 kW or 72 hp. The

ring roller mill needed is a 1.09 m (43 in.) unit drawing up to 75 hp and equipped with a dry classifier whose fan draws an additional 60 to 75 hp (Reference 3, pages 3C 109-110). The dry cyclone and the dust collector are included with the ring roller mill and the whole unit requires 6.4 m x 7.3 m floor area and 9.9 m headroom.

If a concentrate containing 3-4% moisture is acceptable, then the rotary dryer would not be required and the concentrate from the horizontal filter could be fed directly to the ring roller mill. This alternative not only saves the drying costs but also reduces dust problems which might occur.

A 100t capacity barite storage bin would store more than one day's production. Its volume is 100/4.2/0.65 = 36.6 m^3, approximately 3 m diameter by 5.5 m high. From this bin the mud grade barite could either be bagged or transported in bulk.

14. CONCLUSIONS AND RECOMMENDATIONS

As developed in the previous sections, the Pine Brook barite ore may be concentrated into a mud grade barite product by the relatively simple process of two stage crushing followed by jigging. The jig concentrate is of high enough grade to form the final concentrate, while the jig tailing is dewatered and ground in a rod mill and treated on shaking tables. The shaking table tailing is rejected as final tailing while the shaking table concentrate, together with the jig concentrate, is filtered, dried, ground in a ring roller mill and passes as mud grade barite to the storage bin. The barite product satisfies the requirements of mud grade barite as its specific gravity is at least 4.2, its soluble alkaline earth metal content as calcium is well below 250 ppm and it is finer than 325 mesh. The estimated barite recovery of the plant is 73% and the concentrate amounts to approximately 40% of the feed, that is a concentration ratio of 2.5.

If mud grade barite concentrate of 3-4% moisture content is acceptable, then the rotary drying may be omitted from the flow diagram with further savings in operating and capital costs.

The whole of the test work and the plant design relate to the blended head sample used. If ore characteristics became different from those of the ore used here, further work would be required to evaluate the effects of the ore changes on the concentration processes. The blended head sample is believed to represent an ore with relatively poor separation characteristics. If a higher grade ore with lower clay content would be produced, barite recoveries greater than the 75% obtained here should be feasible. However, if there is demand for locally produced mud grade barite, the ore, as tested, should still be a technically viable product.

The conceptual design given here should not be used as a final plant design. If it was decided to proceed with development, more detailed work on larger, more representative samples would be necessary to improve estimates derived from tests and to further optimize design variables.

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APPENDIX A - Tri-Flo Separator Tests

An Investigation of

HEAVY MEDIA SEPARATION

of Barite from

a sample of Pine Brook ore

submitted by

MINERALS ENGINEERING CENTRE,

TECHNICAL UNIVERSITY OF NOVA SCOTIA

Progress Report No. 1

Project No. L.R. 3258

NOTE:

This report refers to the samples as received.

The practice of this Company in issuing reports of this nature is to require the recipient not to publish the report or any part thereof without the written consent of Lakefield Research.

LAKEFIELD RESEARCH
A DIVISION OF FALCONBRIDGE LIMITED

January 19, 1987

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INTRODUCTION

Dr. Les Adorjan of the Minerals Engineering Centre, Technical University of Nova Scotia requested that Tri-Flo heavy media tests be run on a deslimed sample of Pine Brook barite ore to produce as high a grade product as possible. Authorization was given in their Purchase Order No. 0044.

The testwork was observed by Mr. Ron Collings of Energy, Mines and Resources Canada.

LAKEFIELD RESEARCH

R.S. Salter

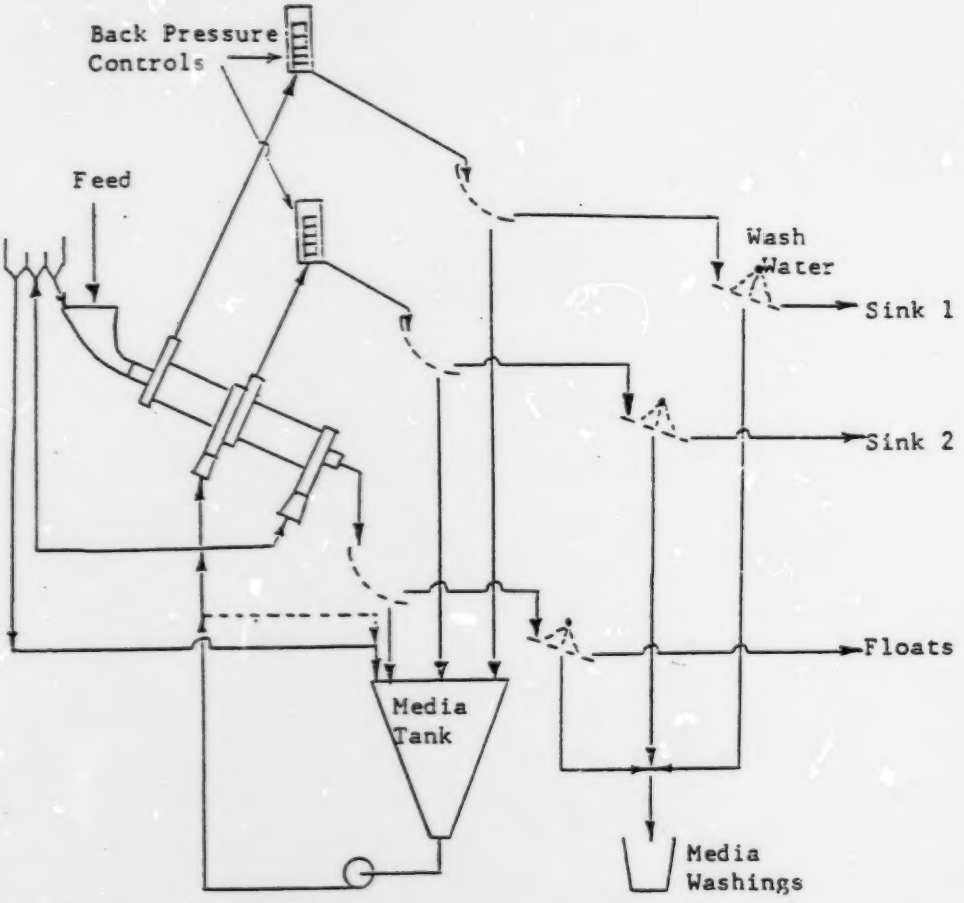
General Manager

A.C.T. Bigg, P. Eng.

Senior Project Engineer

SUMMARY

1. Circuit and Operation



Summary - Continued

1. Circuit and Operation - Cont'd

The Tri-Flo 150 circuit as operated at Lakefield Research is shown on the preceding page. The variables investigated during the testwork were media composition, media density and back pressure. The media consisted of mixtures of atomized ferrosilicon (Hoechst Cyclone 40) and magnetite (minus 200 mesh). The initial adjustments to the media density were made whilst recycling the media directly through the media tank. Final adjustments were made with the Tri-Flo separator in the circuit. With the media operating as required, approximately 20 kg of minus 5.6 mm plus 30 mesh ore (516 μm) was fed into the separator within a time period of 5 to 10 minutes. Pulp densities were taken again at the completion of the run. The oversize products from the DSM screens were collected on secondary screens and washed at leisure.

2. Feed Sample

The ore as received had been crushed and sized at minus 5.6 mm and plus 0.5 mm. The ore was screened once more at 30 mesh (516 μm) and a small amount (<2 % weight) of minus 30 mesh material removed. The average feed assay as calculated from the test results was 31.9 % Ba at an average feed specific gravity of 3.60.

3. Results

Some segregation by size between samples was noted as the tests were being run. However apart from Test No. TF3 the results all fell on a well defined recovery curve (see Figure 1). Test No. TF3 had a lower feed grade.

Figures No. 1 to 3 show the Ba recovery vs. weight % recovery, Ba assay and the specific gravity of the concentrate. A product with a specific gravity of 4.2 can be produced at a Ba recovery of 75 % (50 % Ba assay) and with a weight rejection of 53 %.

Summary - Continued

3. Results - Cont'd

Table No. 1 - Summary of Operating Conditions

Test No. TF	Media Densities, g/L					Gauge Pressures, psi					Back Pressure, mm		Media %	Weight % Recovery		
	Feed	Sink 1	Sink 2	Float	△ S1-F1	Sink 1 Feed			Sink 2 Feed					Sink 1	Sink 2	Float
						1	2	△1-2	1	2	S1	S2	FeSi			
1	2565	3095	3275	2080	1015	35.0	34.0	1.0	29.0	NA	495	525	100	59.8	5.5	34.7
2	3020	3115	3140	2850	265	42.0	42.0	0.0	36.5	NA	495	525	75	58.6	8.0	33.4
3	3385	3445	3440	3360	85	42.0	41.0	1.0	35.5	NA	495	525	75	42.7	11.4	45.9
4	3250	3295	3290	3150	145	44.0	42.5	1.5	37.0	NA	495	525	75	49.3	14.2	36.5
5	3210	3250	3265	3100	150	39.5	39.0	0.5	35.0	NA	648	525	75	45.7	17.5	36.8
6	3040	3125	3170	2880	245	41.5	40.5	1.0	36.0	NA	495	779	75	58.4	6.9	34.7

Fig 1. Relationship of weight recovery to barium recovery

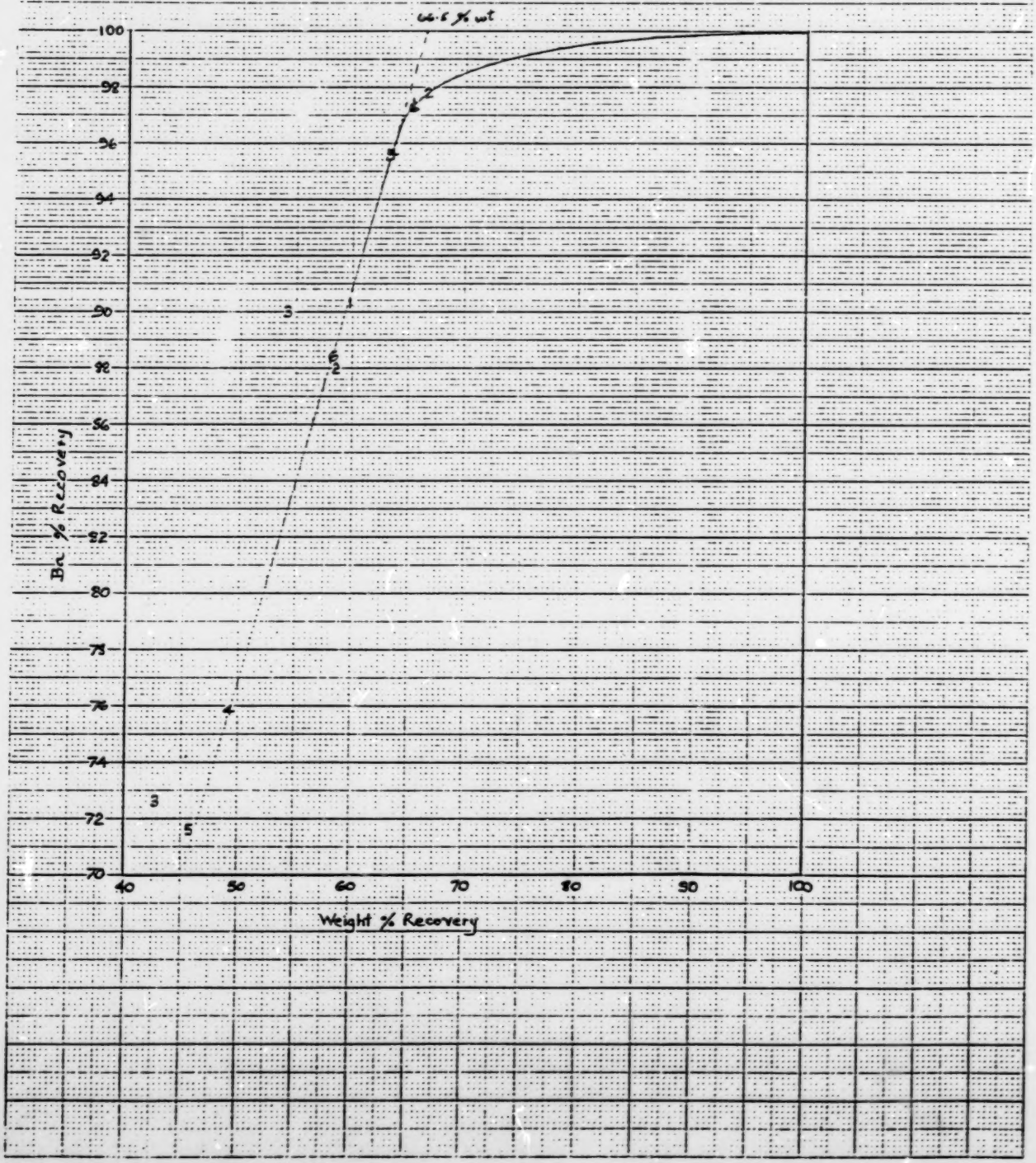


Fig 2. Grade - Recovery Relationship

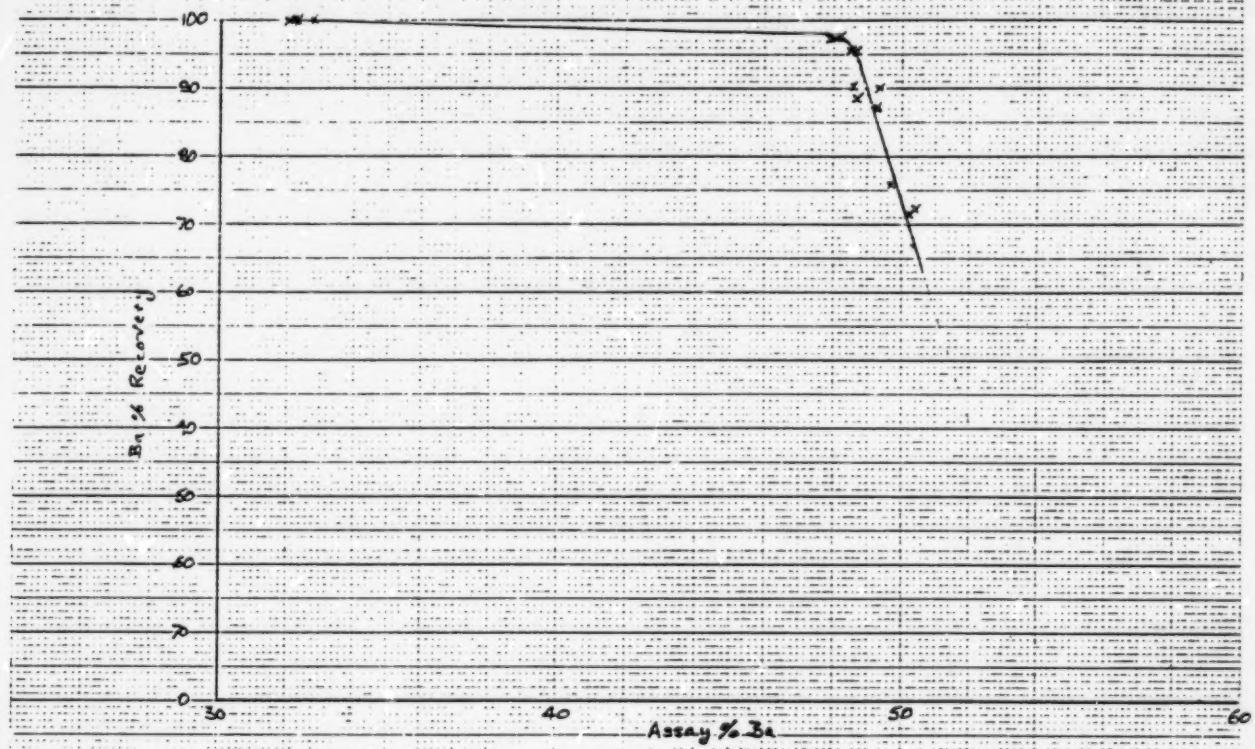
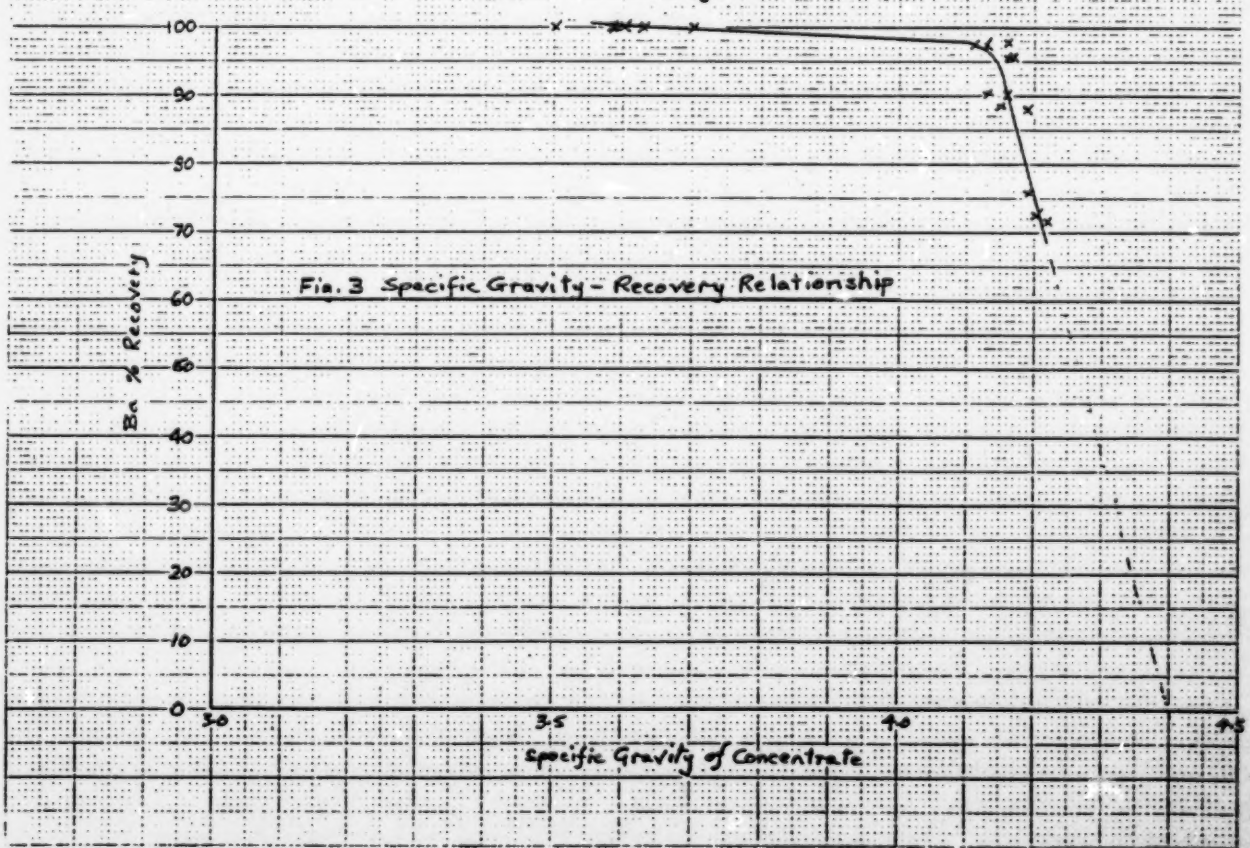


Fig. 3 Specific Gravity - Recovery Relationship



SAMPLE PREPARATION AND DISPOSITION

One drum of ore containing approximately 120 kg of screened sample was received at Lakefield on December 1, 1986. The sample was rescreened on 30 mesh (516 μm) to minimize media contamination with fines. The sample was then split into 6 equal fractions.

The test products were weighed, riffled into 2 portions and one half passed once through a roll crusher to give a nominal minus 10 mesh product. 500 g of this product was riffled out for assay. 300 g of the uncrushed products (or 1/2 the sample if less than 600g) was removed and shipped to Mr. Ron Collings. The remainger of the uncrushed material was shipped to Dr. Les Adorjan.

The crushed rejects and assay rejects are retained at Lakefield.

LAKEFIELD RESEARCH
A Division of Falconbridge Limited
Lakefield, Ontario
January 19, 1987 / slk

TESTWORK RESULTS

TEST NO. TF 1
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	10789	59.81	46.60	4.13	80.33
Sink 2	996	5.52	41.40	3.95	7.10
Float	6254	34.67	2.39	2.99	2.57
Head (Calc.)	18039	100.00	32.19	3.59	100.00
COMBINED PRODUCTS					
Sink 1+2	11785	65.33	47.99	4.11	97.43
Sink 2 + Float	7250	40.19	7.75	3.00	9.67

TEST NO. TF 2
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	10549	58.58	49.30	4.19	87.98
Sink 2	1440	8.00	40.20	3.93	9.79
Float	6019	33.42	2.19	2.89	2.23
Head (Calc.)	18009	100.00	32.83	3.63	100.00
COMBINED PRODUCTS					
Sink 1+2	11990	66.58	48.21	4.16	97.77
Sink 2 + Float	7460	41.42	9.53	3.05	12.02

TEST NO. TF 3
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	7860	42.68	50.40	4.20	72.60
Sink 2	2101	11.41	45.20	4.02	17.40
Float	8454	45.91	6.45	2.95	9.99
Head (Calc.)	18416	100.00	29.63	3.50	100.00
COMBINED PRODUCTS					
Sink 1+2	9961	54.09	49.30	4.16	90.01
Sink 2 + Float	10555	57.32	14.16	3.12	27.40

TEST NO. TF 4
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	8904	49.30	49.70	4.19	75.83
Sink 2	2559	14.17	45.00	4.04	19.73
Float	6599	36.54	3.92	2.91	4.43
Head (Calc.)	18063	100.00	32.31	3.59	100.00
COMBINED PRODUCTS					
Sink 1+2	11463	63.46	48.65	4.16	95.57
Sink 2 + Float	9158	50.70	15.40	3.16	24.17

TEST NO. TF 5
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	8579	45.69	50.20	4.22	71.60
Sink 2	3281	17.47	44.00	4.04	24.00
Float	6919	36.85	3.83	2.92	4.41
Head (Calc.)	18779	100.00	32.03	3.60	100.00
COMBINED PRODUCTS					
Sink 1+2	11860	63.15	48.49	4.17	95.59
Sink 2 + Float	10200	54.31	16.75	3.21	28.40

TEST NO. TF 6
SIZE : -5.6mm + 30 Mesh

PRODUCT	WEIGHT g	WEIGHT %	ASSAYS % Ba	ASSAYS % S.G.	% DISTRIBUTION Ba
Sink 1	10639	58.41	48.70	4.15	88.36
Sink 2	1260	6.92	41.40	3.95	8.90
Float	6314	34.67	2.55	2.89	2.75
Head (Calc.)	18214	100.00	32.20	3.70	100.00
COMBINED PRODUCTS					
Sink 1+2	11900	65.33	47.93	4.13	97.25
Sink 2 + Float	7575	41.59	9.01	3.07	11.64

APPENDIX B - Vibratory Screen Sizing

VIBRATORY SCREEN SIZING

Screen aperture	= .22 in
Solids feed rate	= 44.8 st/h
Percentage finer than screen aperture	= 70.8 %
Percentage finer than half screen aperture	= 40 %
Mean density of ore	= 3.3 kg/cum
Vol. fraction of solids in ROM ore	= .65
Efficiency of screening	= 95 %
Length to width ratio of slots	= 1
Deck number from top	= 2
Percentage of total feed passing to deck	= 50 %
Open area of screen	= 48 %

Dry screening

Fines factor	= 2.2
Efficiency factor	= 1
Slot factor	= 1
Deck factor	= .9
Open area factor	= 1.14
Wet screening factor	= 1

Screen area required	= 10 sqft
Screen width	= 2 ft
Screen length	= 6 ft

APPENDIX C - Rod Mill Sizing

ROD MILL SIZING

INPUT DATA

Wet grinding		
Grate discharge mill		
Open circuit operation		
Volume loading =	40.00	%
Feed rate =,	7.69	tonnes/h
80% passing size of feed =	4200.00	um
80% passing size of product =	360.00	um
Work index of ore =,	11.00	kWh/t
Mill is fed from closed circuit		
Specific gravity of ore =	3.30	

ROD MILL SIZING RESULTS

Number of mills required =	1.00	
Inside diameter =	1.37	m
Mill diameter =	1.52	m
Mill length =	2.44	m
Mill speed =	25.73	rpm
Mill speed =	71.20	% critical
Mill power =	45 kW	61 HP
Replacement rod diameter =	65	mm
Rod length =	2	m

APPENDIX D - Thickener Sizing

THICKENER DESIGN

FLOCCULATED FEED

Solids feed rate	= 1.69 tonnes/hour	
Feed solids conc. by mass	= 2.4 %	
Underflow solids conc. by mass	= 50 %	
Density of solids	= 3.3 g/cucm	
Density of liquid	= 1 g/cucm	
Initial suspension height	= 28 cm	
Batch thickening time	= 5 min	
Retention time	= 10 min	
Number of thickeners required	= 1	
Thickener diameter	= 6 m	(5.122 m)
Thickener depth	= 1.3 m	(.288 m)